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Guidelines for Water Reuse

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The U. S. Environmental Protection Agency (EPA) has identified an immediate short-term objective of developing a wastewater-reuse guidelines document that will significantly increase interest in and assist implementation of wastewater reuse for nonpotable purposes: irrigation and agriculture, industrial, recreation, and nonpotable domestic use. The guidelines have been developed to make water managers and resource planners aware of proven reuse possibilities that may exist nearby and to alert the guidelines user to EPA's encouragement and support for the water-reuse approach. Following a step-by-step approach provided in the guidelines, the water manager and resource planner will have addressed the principal areas of concern in water-reuse programs, including technology, economics, legal issues, institutional arrangements, markets, and public information. The nature of these areas of concern is examined so that the guidelines user can estimate the complexity of the implementation problem and the effort required to overcome it. Case histories provide insight into actual reuse experience for similar communities, and the result to the user of the guidelines is a clear indication of the feasibility of wastewater reuse in the community.

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GUIDELINES FOR WATER REUSE

by

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Foreword

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay among its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research, a most vital communications link between the researcher and the user community.

These *Guidelines for Water Reuse* were prepared as part of this laboratory's research program to assist municipalities in considering and planning for implementation of the non-potable uses of municipal wastewaters as part of wastewater-facilities development in our nation.

Francis T. Mayo
Director
Municipal Environmental
Research Laboratory

Preface

Planning for Multiple-purpose Reuse

The U.S. Environmental Protection Agency (EPA) favors the beneficial reuse of wastewaters, recognizing that the planned reclamation and reuse of wastewater is consistent with EPA's mandate for prudent management and use of our nation's water. The perceived benefits in water reuse are several:

- **Conservation of water,** saving highest-quality freshwater supplies for those purposes that require it;
- **Recycling of nutrients** in wastewater for beneficial use in agricultural and urban irrigation;
- **Practical cost and energy savings** that can often be achieved by both governmental entities and users of the reclaimed water;
- **Reduction in the discharge of pollutants** to watercourses;
- **Realization of other public priorities,** such as preservation of open space for its aesthetic and recreational value;
- **Encouragement of industrial recycling,** greatly reducing projected industrial water use and discharge problems associated with industrial wastewater.

During the past decade, EPA has taken definite steps to encourage consideration of water-reuse opportunities as an integral part of wastewater-facilities' development in cities and towns across the country. EPA has, for example, pressed vigorously for the land treatment of wastewater to take advantage simultaneously of soils' treatment properties and the nutrient value in wastewater for agricultural crops. Since passage of PL 92-500 in 1972, EPA has administered the construction grants program providing funding for water-pollution control facilities and related systems which encourage reuse of wastewater nutrients through revenue producing projects. In response to a 1979 Presidential directive, EPA and three other agencies have cooperated in a joint task-force effort to identify specific measures to encourage water conservation and reuse.

EPA has supported preparation of these *Guidelines for Water Reuse* to assist municipalities in considering and planning for implementation of programs for the nonpotable reuse of municipal wastewaters. The manual is intended to provide municipal leaders with thorough discussion of the technical, economic, financial, legal, and public-involvement issues likely to be encountered in developing a reuse program.

A broad range of nonpotable reuse options—agricultural, urban (such as in dual distribution systems), water recharge, industrial and recreational—are explored.

As it relates to reuse of wastewaters for agricultural purposes, this *Guidelines'* focus has purposely been limited to "multiple-purpose" applications. Under proposed EPA guidelines ("Strategies for Funding of Multiple-Purpose Projects," Office of Water and Waste Management, U.S. Environmental Protection Agency, June 1979), multiple-purpose projects are defined as projects that accomplish a water pollution control objective and at least one other acceptable purpose. The other acceptable purposes can include treatment and agricultural or industrial consumption. Under proposed EPA funding guidelines, all elements of a multiple-purpose project may be eligible for at least some degree of federal funding.

By way of comparison, single-purpose projects are designed solely to satisfy requirements for a National Pollutant Discharge Elimination System (NPDES) permit. There already exist clear technical guidance and funding policy on virtually every aspect of single-purpose projects, including land-treatment projects. In fact, a single-purpose land-treatment project not only is eligible for up to 75-percent Federal Construction Grants Program reimbursement, but also, by definition, constitutes an innovative and alternative project eligible for additional financial incentive under the Clean Water Act of 1977, PL 95-217.

Land treatment of wastewater, as a cost-effective means of meeting an NPDES permit requirement, is a single-purpose application, while a wastewater-reuse project using effluent that has been treated to a point suitable for discharge to a waterway is a multiple-purpose project. The distinction may be important to readers of these *Guidelines*. For multiple-purpose reuse— for example, for development of a water-reclamation and irrigation reuse system in which the primary purpose is optimum agricultural use of the reclaimed water (as opposed to a combined treatment and reuse of the wastewater by applying it to soils at specified rates)—guidance is less clear, precedents fewer, and prospects for EPA funding uncertain.

At this writing, EPA is finalizing its criteria for funding of multiple-purpose projects. The Agency's intention is to maximize the public benefit of funds that have been made available by Congress, attempting to balance the Agency's water-pollution control mandate with pressing priorities for conservation and reuse of wastewater.

The uncertainty over EPA funding of reuse projects should not, itself, cloud the outlook for reuse projects. In some cases, the intangible benefits of reuse outweigh pure cost considerations, and, in many others, the value to the user(s) of reclaimed water as a resource is such that availability of additional funding becomes less relevant in evaluating the project's merits. Some of the case histories presented in these *Guidelines* illustrate instances in which the opportunity to use reclaimed water for beneficial purposes, without EPA construction grants, presented compelling alternative direction to water and wastewater managers and municipal leaders.

Abstract

The U.S. Environmental Protection Agency (EPA) has identified an immediate short-term objective of developing a wastewater-reuse *Guidelines* document that will significantly increase interest in and assist implementation of wastewater reuse for nonpotable purposes: irrigation and agriculture, industrial, recreation, and nonpotable domestic use. The *Guidelines* have been developed to make water managers and resource planners aware of proven reuse possibilities and to alert the guidelines user to EPA's encouragement and support for the water-reuse approach.

Following a step-by-step approach provided in the *Guidelines,* the water manager and resource planner will have addressed the principal areas of concern in water-reuse programs, including technology, economics, legal issues, institutional arrangements, markets, and public information. The nature of these areas of concern is examined so that the *Guidelines* user can estimate the complexity of the implementation problem and the effort required to overcome it. Case histories provide insight into actual reuse experience for similar communities, and the result to the user of the *Guidelines* is a clear preliminary indication of the feasibility of wastewater reuse in the community.

The *Guidelines* are designed to show that water reuse may represent an effective problem-solving measure for a community or region. The *Guidelines* user is led through a flow sequence diagram that shows how the *Guidelines* can be used to establish the viability of reuse on a case-by-case basis. The following issues are addressed in various chapters of this resource document: identifying sources of reusable water; identifying water reuse applications; inventorying water use and cost for potential users; estimating transportation and storage costs; dewatering water quality requirements; estimating costs of additional treatments; determining cost allocation and user charges; institutional, legal, and financial considerations; identifying health agencies and procedures; marketing the resource; meeting dependability requirements; identifying financing mechanisms; supporting public-information activities; and taking steps toward implementing a program.

This document is submitted in fulfillment of Contract No. 68-03-2686 by Camp Dresser & McKee Inc. under the sponsorship of the U.S. Environmental Protection Agency. The *Guidelines* were completed in March 1980.

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Multiply	By	To Obtain
Acres	43,560	ft^2
Acre-ft	325,851	gallons
Acre-ft	1,234	m^3
cu ft	28.32	l (liters)
cu ft	0.03704	cu yd
cu ft	7.481	gallons
cu ft/second	0.6463	mgd
cu ft/second	448.8	gpm
cu ft/second	1.98	acre-ft
cu yd	0.765	m^3
°F	0.555 (°F-32)	°C
ft	0.3048	m
gal	3.785	l
gal, water	8.345	lb, water
gpm	0.06308	l/s
gpm	5.458	m^3/d
hp	0.7457	Kw
in	25.4	mm
lb (mass)	0.4536	kg
mil gal	3,785	m^3
mil gal	3.07	acre-ft
mgd	3,785	m^3/d
mgd	1.55	cu ft/second
miles	1.609	km
sq ft	0.0929	m^2
tons (short)	907.2	kg

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I

Introduction

A Rationale for Reuse

WHY WATER REUSE? WHO WOULD BE INTERESTED?

Many communities are, or soon will be, reaching the limits of their available water supplies. By instituting conventional conservation measures—water-saving plumbing fittings, leak detection and reduction, and innovative pricing policies—communities may be able to defer for some years the need to develop additional water resources, but urban growth and development will inexorably press on existing supplies. Additional water resources will be needed, sooner or later.

But many communities do not have ready access to additional sources of water. Available groundwater and surface waters have been fully allocated (Figure I-1). Even when new water sources are available, they are inevitably more costly to develop (even allowing for inflation) than existing supplies, because the first supplies naturally exploited the lowest-cost options. To develop additional supplies requires going further, or shifting from groundwater to surface waters, or using lower-quality or polluted sources, all of which choices entail greater costs for either transmission or treatment.

Tapping of polluted sources has potential effects that go beyond the increased cost of additional treatment. This sort of "indirect reuse" of polluted water may expose people to health risks not associated with protected sources. For, although the development of modern water-treatment practices has enabled us to draw water supplies from large rivers that drain urban and industrial areas without fear of typhoid, cholera, dysentery and other enteric infectious diseases, the chemical revolution of the last decades has created vast numbers of long-lasting synthetic organic chemicals that pose a health threat of their own. Some of these chemicals have been identified as being carcinogenic, even in trace concentrations, when ingested over long periods of time. These synthetic organic chemicals are not easily monitored or removed in treatment processes. (The health concerns associated with drawing upon polluted sources apply even more forcefully to reuse of wastewaters for potable purposes. Potable reuse is not considered in this manual.)

Use of reclaimed water for nonpotable purposes, therefore, offers the potential for exploiting a "new" resource that can be substituted for existing sources. By "source substitution"—replacing with reclaimed water the potable water used for nonpotable purposes—an increased population can be served from an existing source. Development of new, costlier sources that are quite possibly of poorer quality becomes unnecessary. Source substitution is not a new idea. More than 20 years ago, this concept was endorsed by the United Nations Economic and Social Council in its policy for planned water reuse: "No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade."[1]

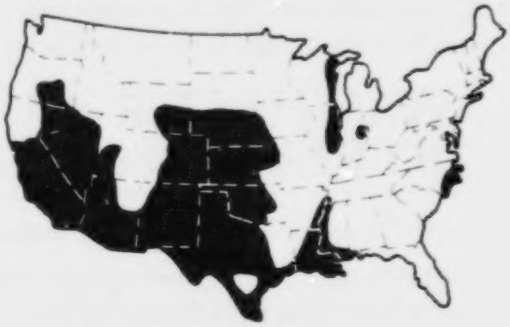

Figure I-1. Areas facing water shortages by the year 2000.

Another factor that tends to favor water reuse is the effect of technological advances made in wastewater treatment. Stringent water-pollution control requirements have resulted in the construction of wastewater-treatment plants that turn out effluents of high quality, often "too good to waste." Many of these plants incorporate costly nutrient-removal processes, processes that are generally not necessary if the effluent is to be reused. For urban irrigation, for example, the nutrients are beneficial and should not be removed.

To summarize, many factors tend to interest communities in nonpotable reuse (see Figure I-2).

Another situation which might call for consideration of reuse, but in the long term, is that of a community already drawing upon a polluted source for potable supplies. Satisfying proposed water-supply treatment standards that would require installation of processes for removing synthetic organics together with concomitant monitoring might prove more costly than shifting to a protected water source. If the protected source were limited in yield, the demand upon the source could be curtailed by nonpotable reuse of wastewaters. Reuse might be promoted because it satisfies the conservation ethic, but it will only be widely adopted, and successful, if it is economical.

IN COMMUNITIES WHERE...

- **Freshwater supplies are limited,**
- **Freshwater supplies of good quality are limited by surface- or groundwater pollution,**
- **New freshwater supplies must be developed at increasing distance from and/or expense to the community,**
- **A single large water user or class of users can tolerate a lower grade of water provided at reasonable costs, and/or**
- **Receiving-water quality requirements are such that costly wastewater-treatment facilities must be built...**

...WASTEWATER REUSE MAY OFFER SOME VERY REAL COMMUNITY BENEFITS:

- **An increase in total available water supply,**
- **Conservation of highest-quality supplies for potable use and other uses that demand that quality,**
- **Expansion of beneficial industrial/commercial, agricultural or recreational opportunities in your area, and/or**
- **Obtaining of capital and operating economies in your water management program.**

Figure I-2. Many factors favor water reuse, and can be seen behind the implementation of reclamation/reuse throughout the United States.

WHERE DOES REUSE BEGIN?

Nonpotable reuse has a long history, with "sewage farms" (farmlands irrigated with raw wastewater) in operation for more than a century in Europe. Large-scale industrial reuse was initiated almost half a century ago in the United States. In 1978, a study sponsored by the U.S. Department of Interior Office of Water Research and Technology identified over 500 reuse sites in the U.S., using a total of 680 million gallons per day (mgd) of reclaimed water[2].

In current reuse planning, the obvious place to begin is with a large user. Industrial and agricultural users fall into that category, as does irrigation of some recreational lands. The next step would be to serve many large users, including industrial, commercial, and public enterprises, with a limited nonpotable distribution system. This is the beginning of a dual distribution system (see Figure I-3 for an example of one system in operation for over 50 years). A third step would be to serve the residences, beginning with multifamily residential units and finally serving individual homes.

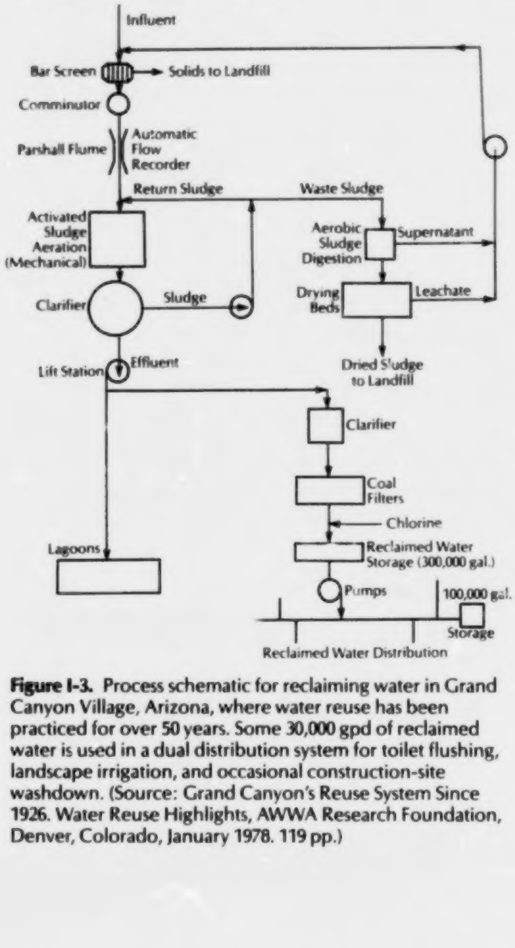

Figure I-3. Process schematic for reclaiming water in Grand Canyon Village, Arizona, where water reuse has been practiced for over 50 years. Some 30,000 gpd of reclaimed water is used in a dual distribution system for toilet flushing, landscape irrigation, and occasional construction-site washdown. (Source: Grand Canyon's Reuse System Since 1926. Water Reuse Highlights, AWWA Research Foundation, Denver, Colorado, January 1978. 119 pp.)

The nonpotable uses now practiced include agricultural and landscape irrigation (including multifamily, residential lawn irrigation), industrial processing, cooling and recreation. Landscape irrigation for individual residences and reuse for internal fixtures, such as toilets, in industrial and commercial buildings, recreational centers, and residences, are still in their infancies, and will likely be the last uses to be explored.

Practical Concerns in Reuse Planning

IS RECLAIMED WATER SAFE?

A major advantage of nonpotable reuse lies in the fact that chemical contaminants in the reclaimed water cannot have much effect on health. The need still exists, however, for control of infectious bacteria and viruses to which the public might be exposed through consumption of raw food crops irrigated with inadequately-treated effluent, through exposure to aerosols emanating from spray-irrigation devices or industrial cooling towers, or through inadvertent ingestion at a recreation area using reclaimed water.

Methods for monitoring the presence of enteric viruses are not yet standardized, and criteria have not yet been established to define acceptable concentrations of such viruses. Bacterial standards that have been developed are implicitly considered to be surrogates for viral safety, even when waters are drawn from highly polluted sources (and there is a growing body of evidence that supports the validity of this practice). Because safe levels of exposure are not certain and because modes of transmission such as inhalation of aerosolized viruses are poorly understood, user and public safety is a prime concern in reuse planning.

Another safety consideration involves the possibility of cross-connections in a nonpotable water distribution system associated with a potable system. A sound historic basis for this question exists: in early nonpotable systems using untreated water drawn from polluted sources for firefighting, cross-connections did occur and resultant outbreaks of disease were recorded.

To date, very few states provide any guidance or controls on design and operation of dual distribution systems. Obviously, if reclaimed water were treated to levels that closely approach or meet the bacterial standards of the Environmental Protection Agency Drinking Water Regulations, the rare instance of ingestion resulting from a cross-connection or inadvertent use should not pose a serious health problem. In any event, sound plumbing practices—including such features as backflow-prevention devices, where necessary—and adequate regulations and enforcement should mitigate the problem.

WHO TAKES THE INITIATIVE?

Water supply and wastewater disposal are functions that are often managed separately and are highly fragmented amongst communities. Local initiative for water reuse can come from a water purveyor who needs additional resources, or a wastewater-disposal agency that seeks a more economical scheme for wastewater management. A large water user might explore reuse when conventional water supplies are too expensive or when water rights are unavailable.

The initiative can come from many places, but successful reuse will require the cooperation of water supply, wastewater and regulatory authorities and the public served. Implementation can be easier where the water supply and wastewater-disposal functions are integrated and where water management in an area is regionalized.

WHO PAYS?

Financing of reuse facilities must be on a sound basis to assure that adequate income is derived from the sale of the nonpotable water to provide for the facilities and their proper operation, including water-quality monitoring. In many reuse operations, the wastewater effluent has been considered a waste product rather than a resource, and has been given away free or with only a nominal charge. Such waters are often of poor quality and have tended to give reuse a bad name. Sound fiscal management of a reuse program, which in many cases will include a rational and equitable system of charging, will help assure reliability of operation, because the customers will then demand a satisfactory product and the reuse agency will have the funds available to provide the service.

Keeping in mind the desirability of financing reuse systems through sale of reclaimed water, some entities have pursued reclamation and reuse with other objectives foremost: to promote desirable land use, for example, or to improve water quality, or to attract or retain local industrial growth. The financing arrangements in these situations might be quite reversed, even while recognizing the intrinsic value of the reclaimed-water product. In Santa Rosa, California, where agricultural irrigation with 43,000 acre-feet per year of reclaimed water will constitute the largest reuse system in the U.S., it was originally proposed that farmers would be paid to accept the reclaimed water, and, under the current plan, farmers will be offered low-interest loans to develop on-farm systems for distribution of the irrigation waters.

Federal and state subsidies, through programs such as those funded under the Clean Water Act of 1977 (PL 95-217), can provide financial assistance for the planning, design and construction of pollution-control facilities. Under some circumstances, such grants can be applied to the implementation of reuse programs. But long-term financing should not be dependent on such subsidies.

Contents of the Reuse Guidelines

These guidelines are intended to assist you in developing a systematic and thorough plan-of-study for local applications of wastewater reclamation and reuse technology. Major technical and non-technical issues are identified and discussed, drawing on the experiences which other municipalities and utility districts have encountered in implementing their own water-reuse programs. By using the guidelines in a step-by-step approach recommended in Chapter 1, the user can complete a preliminary feasibility study on reuse and—working with potential users, other agencies, and the interested public—can make determinations as to what reuse alternatives merit closer evaluation in detailed engineering studies.

The remaining chapters deal with major issues in reuse planning. Chapter 2 examines the technical aspects of reuse: matching sources to markets. Chapter 3 examines the economic issues: an analysis of freshwater costs versus reclaimed-water costs. The legal and institutional issues involved in any reuse plan are discussed in Chapter 4. Chapter 5 helps the user to formulate a sound financial plan for the reuse program. The issue of public involvement in reuse planning, and the means of encouraging active public participation, are discussed in Chapter 6.

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1. UN Economic and Social Council. Water for Industrial Use. United Nations Report No. E/3058 ST/ECA/50, New York, 1958.
2. Culp/Wesner/Culp and M.V. Hughes, Jr. Water Reuse and Recycling, Vol. 1: Evaluation of Needs and Potential. OWRT/RU-79/1, prepared for the Department of Interior, Office of Water Research and Technology, Washington, D.C., April 1979.

Overview—A Planning Approach

1

Step-by-Step Guidelines

These guidelines for nonpotable water reuse describe a step-by-step approach for investigating the possibility of developing a new water resource in your area. This resource—reclaimed water—is potentially a valuable one, suitable for use in a variety of ways. Throughout these guidelines, we have presented examples of communities that have chosen to apply reclaimed water to their specific needs: for urban irrigation, agriculture, residential use, landscape maintenance, industrial processing and cooling, groundwater recharge, and recreation. The experiences that these communites have faced in implementing their reuse programs are as varied as the applications themselves. One key goal of these guidelines, therefore, is to outline a thorough, systematic approach to planning for wastewater reuse, so that planners can make sound preliminary judgments about the local feasibility of reuse—taking into account the full range of important issues that have been addressed in implementing earlier programs or that might be encountered in future programs.

We have arranged these guidelines by issues, devoting separate chapters to each of the technical, economic, legal/institutional, financial, and public-involvement considerations that a reuse planner might face. You can use these guidelines, therefore, either to find answers to specific questions about reuse (e.g., how does one estimate the costs of conveying reclaimed water to a user), or to develop, from scratch, a well-conceived program for studying and determining the prospects for reuse in your area.

Phased Approach

Figure 1-1 illustrates a three-phased approach to reuse planning that groups reuse-planning activities into successive stages of preliminary investigations, screening of potential markets, and detailed evaluation of selected markets. Through all of these stages, public-involvement efforts provide guidance to the planning process, and from the very outset you will be taking steps that will support project implementation, should reuse prove to be feasible. Each stage of activity builds on previous stages until you have enough information to develop a conceptual reuse plan for your community and to begin negotiating the details of reuse with selected users.

PRELIMINARY INVESTIGATIONS

This is a fact-finding phase, meant to rough out physical, economic, and legal bounds to the wastewater-reuse plan. You will be concerned primarily with locating all potential sources of effluent for reclamation and reuse and all potential markets for this reclaimed water. You will also be identifying the institutional constraints and enabling powers that might affect a reuse plan in your area. This phase should be approached with a broad view. Exploration of all possible options at this early stage in the planning program will both establish a practical context for your plan and help to avoid creating dead-ends in the planning process.

The questions to be addressed in this phase include the following (shown in parentheses are the chapters of this manual in which related issues are discussed):

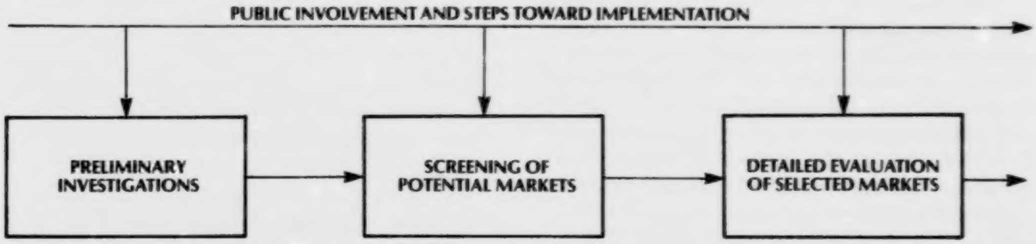

PUBLIC INVOLVEMENT AND STEPS TOWARD IMPLEMENTATION
PRELIMINARY INVESTIGATIONS
SCREENING OF POTENTIAL MARKETS
DETAILED EVALUATION OF SELECTED MARKETS

Figure 1-1. Phases of program planning typically used in pursuing local water-reuse opportunities.

- What local sources of effluent might be suitable for reuse? (Chapter 2)
- What are the potential local markets for reclaimed water? (Chapter 2)
- What public-health considerations are associated with nonpotable reuse, and how can these be addressed? (Chapter 2)
- How would water reuse "fit in" with present use of other water resources in the area? (Chapters 2 & 4)
- What are the present and projected user costs of freshwater in the area? (Chapter 3)
- What existing or proposed laws and regulations affect reuse possibilities in the area? (Chapter 4)
- What local, state or federal agencies must review and approve implementation of a reuse program? (Chapter 4)
- What are your legal liabilities as a purveyor of reclaimed water? (Chapter 4)
- What sources of funding might be available to support a reuse program in your area? (Chapter 5)
- What nonpotable-reuse system would attract the public's interest and support in your area? (Chapter 6)

The major task of this phase involves preliminary market assessment, as represented in the second question above. You will need to define the water market, probably through discussions with water wholesalers and retailers, and to identify major water users in the market. Several regional urban reuse studies in California have used a water-demand figure of about 50,000 cubic feet per month as the minimum level-of-use that defines "major" water users.[1,2] Initial contact by telephone and follow-up letter will probably be necessary to determine what portion of total water use might be satisfied by reclaimed water; that is, what portion of each potential user's total water use is applied to nonpotable functions, what quality of water is required for each function and how use of reclaimed water might affect the user's operations or discharge requirements.

Obviously, it will be important, even at this early stage, to develop good working relationships among wastewater managers, water-supply agencies and potential reclaimed-water users. Potential users will be concerned with the quality of reclaimed water and reliability of its delivery; they will also want to know that you are fully cognizant of state and local regulations that apply to use of reclaimed water, and sensitive to constraints such as hookup costs or additional wastewater-treatment costs that might affect their ability to use the product.

SCREENING OF POTENTIAL MARKETS

The essence of this phase is a comparison between the unit costs of freshwater to a given market and the unit costs of reclaimed water to that same market. On the basis of information gathered in your preliminary investigations, you may already have developed one or more "intuitive projects,"[3] projects that are obvious possibilities or that just "seem to make sense." For example, if a large, water-using industry is located next to a wastewater-treatment plant, there exists a strong potential for reuse: the industry has a high demand for water, and costs of conveying reclaimed water would be low. But the value of reclaimed water—even to such an "obvious" potential user—will depend on:

- the quality of water to be provided, as compared to the user's requirements;
- the quantity of water available, and the ability to meet fluctuating demand;
- the effects of laws that regulate this reuse, and the attitudes of agencies responsible for enforcing applicable laws; and
- the present and projected future cost of freshwater to this user.

These questions all involve detailed study, and it lies beyond the capacities of most public entities to apply the required analyses to every reuse possibility in their areas. A useful first step is to identify a wide range of candidate reuse systems that might be suitable in the area and then to "screen" these alternatives down to a handful of promising project alternatives for detailed evaluation. In order to establish the most complete list of reuse possibilities, you should consider not only the different types of nonpotable reuse that could improve use of water resources in your area, but also such factors as:

- Different levels of treatment—if advanced wastewater-treatment (AWT) is currently required prior to discharge of effluent, there might be cost savings available if a market exists for secondary effluent;
- Different project sizes—the scale of reuse can range from conveyance of reclaimed water to a single user to the general distribution of reclaimed water for a variety of nonpotable uses;
- Different conveyance networks—different distribution routes will have different advantages, taking better advantage of existing rights-of-way, for example, or serving a greater number of users.

In screening the project possibilities, you will probably identify as the pivotal question the economic cost of each alternative. Chapters 2 and 3 provide general guidance on selecting and sizing facilities for treatment, storage and distribution of reclaimed water in different types of reuse systems. In addition, reconnaissance-level techniques like those presented in Chapter 3 can help you to consider both capital and operating costs for the treatment, conveyance and storage requirements of each candidate reuse system you have identified.

Beyond this comparison of the overall costs estimated for each alternative, several other criteria can be factored into the screening process. The East Bay Dischargers Authority (EBDA) in Oakland, California, used demonstrated technical feasibility as one criterion, and the comparison of estimated unit costs of reclaimed water with unit costs of freshwater, as another[1]. East Bay Municipal Utility District (EBMUD), also of Oakland, used an even more complex screening process[2] that included comparison of weighted values for a variety of objective and subjective factors, such as:

- How much flexibility would each system offer for future expansion or change?
- How much use of freshwater would be replaced by each system?
- How complicated would program implementation be, given the number of agencies that would be involved in each proposed system?
- To what degree would each system advance the "state-of-the-art" in reuse?
- What level of chemical or energy use would be associated with each system?
- How would each system affect land use in the area?
- How do the systems compare if projects receive grant funding, and how if no such funding is available (grant funding tends to favor capital-intensive projects)?

Your review of user requirements, compared with what you know to be available through reclaimed water, could enable you to narrow down the list of potential markets to a few selected markets for which reclaimed water could be of significant value.

DETAILED EVALUATION OF SELECTED MARKETS

The evaluation steps contained in this phase represent the heart of the analyses necessary to shape your reuse program. Following the screening steps above, you will have established a ranking of "most-likely" projects, and you will know what the present freshwater consumption and costs are for selected potential users. In this phase, by looking in more detail at the conveyance routes and storage requirements of each selected system, you will be able to refine your preliminary cost estimates for delivering reclaimed water to these users. Funding options can be compared, user costs developed, and a comparison made between the unit costs of freshwater and of reclaimed water for each selected system. It will be possible also to evaluate in more detail the environmental, institutional and social aspects of each project. You will be addressing the following questions:

- What are the specific water-quality requirements of each user? What fluctuation can be tolerated?
- What is the daily and seasonal water-use demand pattern for each potential user?
- Can fluctuations in demand best be met by pumping capacity or by storage? Where would storage facilities best be located?
- If additional treatment of the effluent is required, who should own and operate the additional-treatment facilities?
- What costs will the users in each system incur in tying-into the reclaimed-water delivery system?
- Will industrial users in each system face increased treatment costs for their waste streams, as a result of using reclaimed water? If so, is increased internal recycling likely, and how will this affect their water use?
- Will water customers in the service area allow project costs to be spread over the entire service area?
- What interest do potential funding agencies have in supporting each type of reuse program being considered? What requirements would they impose on a project eligible for funding?
- Will use of reclaimed water force agricultural users to alter irrigation patterns or to provide better control of return flows?
- What payback period is acceptable to users who must invest in additional facilities for on-site treatment, storage or distribution of the reclaimed water?
- What are the prospects of industrial source control measures in your area, and would institution of such measures reduce the additional-treatment steps necessary to permit reuse?
- How "stable" are the potential users in each selected candidate reuse system? Are they likely to remain in their present locations? Are process changes being considered that might affect their ability to use reclaimed water?

CASE STUDY:
Screening: One Agency's Approach

One of the most detailed screening processes yet attempted on reuse alternatives is that completed in 1978 by the East Bay Dischargers Authority (EBDA), Hayward, California.

EBDA was formed in 1974 to handle wastewater effluent disposal from two cities and three sanitary districts. In 1983, EBDA facilities that are now under construction will be in operation, including four treatment plants (total capacity 50 mgd) and a reversible-flow force main connecting the four plants along a 20-mile corridor.

Recognizing the reuse possibilities of its treatment/disposal system, EBDA initiated a fine-grained survey of the urban reuse prospects. The principal challenges in the effort were found to be (1) extracting potentially viable reuse schemes from literally thousands of possibilities, and (2) integrating the survey and subsequent evaluation with other interested agencies.

EBDA addressed the second challenge first. A Reclamation Advisory Policy Committee was formed, with representatives from two water districts, a regional park district official, a representative from the city where the EBDA outfall discharges to the Bay, two representatives from industrial associations, two from EBDA, and one interested private citizen. The Committee was charged with:

- reviewing program feasibility;
- judging program acceptability;
- resolving overlapping or conflicting responsibilities;
- keeping the public informed of the program's progress; and
- recommending reuse policies to EBDA.

Then, with the help of a consultant, EBDA and the committee initiated a 10-step screening process, as follows:

1. In listing all possible types of reuse, EBDA identified 65 possibilities.
2. In order to screen the list down to those types most feasible in the project area, EBDA compared the types of reuse both to current and anticipated regulations of the State's Department of Health Services, and to the experience obtained in other parts of the country in each type of reuse. A set of priority ratings was established to quantify the comparisons, with rankings one through five ranging from "(1) demonstrated cost-effectiveness and viability" and "(2) cost effective with moderate institutional viability"... down to "(5) not viable in California without a technological breakthrough." Only those reuse types assigned to priorities 1 and 2 were selected for further study; these included landscape and agricultural irrigation, industrial use, and wildlife enhancement.
3. A total of over 1,000 sites in the 200-square-mile area were identified as possible locations for the priority reuse applications.
4. Of the 1,000 possible priority uses, those that would use less than ten acre-feet per year were deemed uneconomical and dropped from the list.
5. Sample groups among those remaining were selected in order to establish flow/quality requirements and to determine their interest.
6. The list was redrafted; approximately 350 potential users remained in active consideration after Step 5.
7. The remaining potential users were screened in terms of flow volume, distance from source (Figure 1-2), and cost of service. EBDA assumed "minimum" additional treatment (filtration, chlorination), peak flow rates for irrigation users, conveyance velocities of 4-7 feet per second, power costs of $0.04/kWh, ENR of 2900 and 40 years' amortization at 7% interest, capital and O&M annual costs of $20 per acre-foot per year for filtration and chlorination, and $15 per acre-foot per year for pumping. Only those potential users whose costs would be less than $250 per acre-foot were retained for consideration, as this cost was considered to be competitive with freshwater costs at this degree of approximation.
8. The list was redrafted; 140 potential users remained.
9. Preliminary system layouts and piping cost estimates were prepared on each of the 140 candidates; where unit costs of pipeline alone amounted to more than $200 per acre-foot, the candidate was eliminated from further consideration, as total costs of additional treatment, piping, pumping, and O&M would be prohibitive.
10. Eighteen feasible projects were identified. These included six industrial users, three agricultural users, two golf courses, six parks and three freshwater marshes, using a combined total of more than 13,000 acre-feet per year.

EBDA also established a Technical Advisory Committee, with representatives from each EBDA member agency and the two water districts providing technical guidance and crucial information. The policy and technical advisory committees have continued to work closely with a liaison representative from the State Office of Water Recycling as planning proceeds toward implementation.

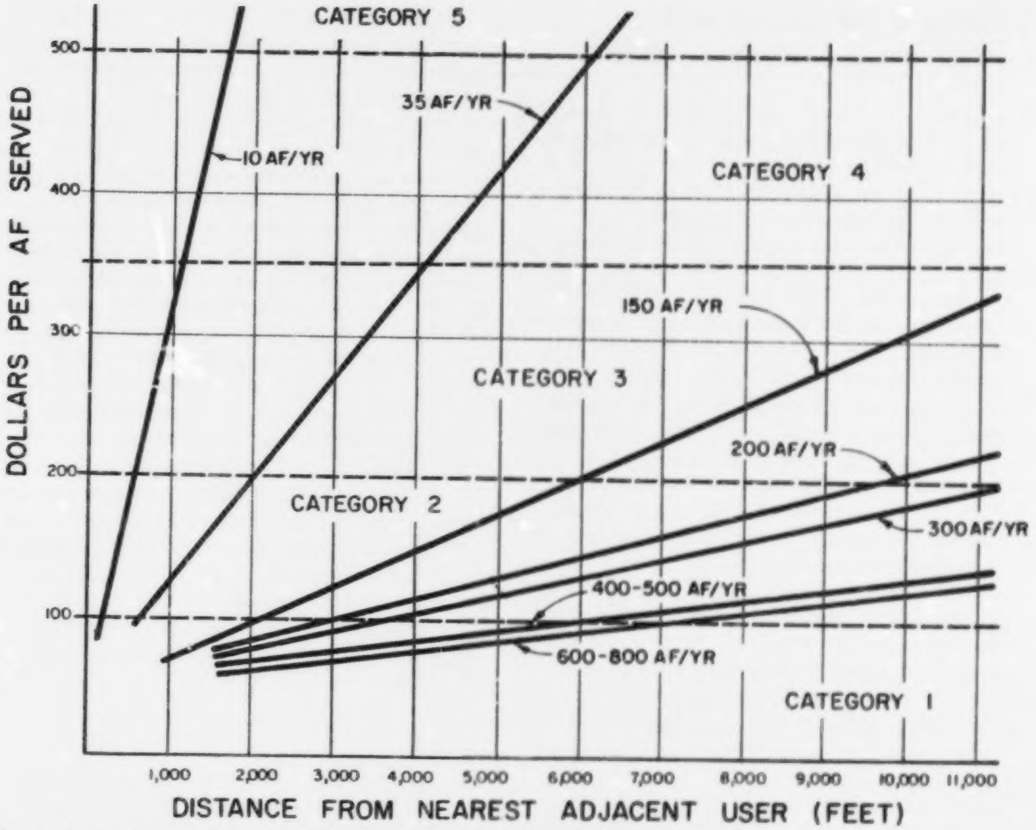


Figure 1-2. Cost curves used by East Bay Dischargers Authority (EBDA) showing estimated incremental unit cost to serve a user from neighboring users. Curves like this one helped EBDA to screen reuse possibilities in its region from about 1,000 candidate locations down to about 18. In this curve, it is seen that delivery of reclaimed water over distances of more than one mile can be economical for large-scale users. (Source: Murphy, D.F. and G. Lee. East Bay Dischargers Authority (EBDA) Reclamation/Reuse Survey. In: Proceedings of the Water Reuse Symposium, Vol. 2, AWWA Research Foundation, Denver, Colorado, 1979. pp. 1086-1098.)

While the EBDA screening process is more highly detailed than many reuse planners will need for their purposes, the Authority found that the benefits of its high credibility among the public and public officials justified the $170,000 survey cost. A Clean Water Act grant helped fund the EBDA survey.

Source: Murphy, D.F. and G. Lee. East Bay Dischargers Authority (EBDA) Reclamation/Reuse Survey. In: Proceedings of the Water Reuse Symposium, Vol. 2. AWWA Research Foundation, Denver, Colorado, 1979. pp. 1086-1095.

As is apparent, many of these questions can be answered only after further consultation with water-supply agencies and prospective users. Both groups will certainly seek more detailed information from you, as well, and you should be prepared to share with them the preliminary findings made in the first two phases of effort.

Your detailed evaluations should lead to a preliminary assessment of technical feasibility and costs. Comparison among alternative reuse programs will be possible, as well as preliminary comparison between these programs and alternative water supplies, both existing and proposed. In this phase, economic comparisons, technical optimization steps, and environmental-assessment activities leading to a conceptual plan for reuse might be accomplished by working in conjunction with appropriate consulting organizations.

Public Involvement and Steps Toward Implementation

In many examples of reuse, the seller has thought of the effluent, or reclaimed water, as nothing more than a waste to be disposed of.[4] These guidelines adopt a "second-generation" approach to reuse—and this approach starts with recognition of reclaimed water as a resource, a usable and saleable product[5]. There are mutual "needs" to be satisfied: you have a product that you would like to sell, the potential reuser has a legitimate use for reclaimed water, and the general public stands to derive some benefit from supporting a reuse program.

Toward this end, the phases of reuse planning described above should be accompanied by ongoing activities of public involvement and steps toward implementation. These activities are related: your initial contact with potential users of reclaimed water represents both public involvement and an early step toward project implementation. You will be informing the potential user of your interest in implementing a program of reuse, indicating to the user why you believe such a program might make sense in your area, and soliciting the user's interest and any information the user can provide.

Some agencies planning reuse programs have made this type of initial contact by telephone or personal visit and have followed up with written expressions of interest to encourage further involvement. Some have also organized formal advisory committees comprised of individuals from public agencies and various interest groups, in order to take advantage of the additional areas of expertise and broad range of viewpoints represented among the committee members. Public-involvement activities of this kind not only serve the planning process but also help to build a constituency that will support the selected plan.

In later phases of developing a reuse program, public involvement will focus in on the sectors of the public which will be most affected by project implementation: residents and developers (in a nonpotable urban reuse system), employers and employee representatives (in an agricultural or industrial reuse scheme), and neighborhood entities. Above all, your contacts with potential users will enable you to negotiate an acceptable user charge with them, to anticipate potential contractual risks, to establish the operational steps necessary to assure reliable delivery of reclaimed water and safe reuse of the product. During your detailed evaluation of selected markets, you may be ready to obtain some form of preliminary commitment from prospective users, perhaps even negotiating a contract specifying reclaimed-water prices and other factors such as each party's responsibilities and obligations.

If, throughout the planning process, you have diligently sought the cooperation and involvement of potential users, other affected sectors of the general public, and responsible public agencies and funding bodies, you might find project implementation to be little more than the formalizing of arrangements already found to be mutually acceptable—and desirable.

References

1. Murphy, D.F. and G. Lee. East Bay Dischargers Authority (EBDA) Reclamation/Reuse Survey. In: Proceedings of the Water Reuse Symposium, Vol. 2. AWWA Research Foundation, Denver, Colorado, 1979. pp. 1086-1098.
2. East Bay Municipal Utility District, Water Resources Planning Division. Wastewater Reclamation Project Report. Oakland, California, June 1979.
3. Leeds, Hill and Jewett, Inc. Economic and Institutional Analysis of Wastewater Reclamation and Reuse Projects. Report 14-31-001-3177, final report for OWRR C-1912, Office of Water Resources Research, U.S. Department of the Interior, Washington, D.C., 1971. 171 pp.
4. Schmidt, C.J. and E.V. Clements, III. Demonstrated Technology and Research Needs for Reuse of Municipal Wastewater EPA-670/2-75-038. National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, May 1975.
5. Donovan, J.F. and J.E. Bates. Guidelines for Implementing a Municipal Program. Consulting Engineer, Vol. 53, No. 3, September 1979. pp 96-102.

The Technical Issues

2

This chapter addresses the following questions:

- What are the potential sources of reclaimed water in your community?
- What are the potential local markets for reclaimed water?
- What are the water-quality requirements for specific uses?
- What should be considered in assuring water quality?

Sources of Reclaimed Water

LOCATING THE SOURCES

Plotting Information. A logical first step in reuse planning is to locate wastewater-treatment plants (WWTPs) in the study area. At this stage in the plan, a U.S. Geological Survey (USGS) map of 1:24,000 scale (1 in = 2,000 ft) is suitable for plotting the location of treatment facilities. These maps are inexpensive, readily available through USGS outlets, and of a scale appropriate to local or subregional planning. You can also use map overlays to show the locations of elements that might be critical to the reuse plan. These might include:

- residential areas and their principal sewers,
- industrial areas and their principal sewers,
- areas with combined sewers,
- areas of future residential development, and
- locations of potential reclaimed-water users,

as well as other features discussed later in this section.

Primary, secondary and advanced wastewater-treatment (AWT) facilities should be identified, and any conveyance routes between plants should be noted, if the facilities are located at some distance from each other. For example, secondary effluents from plants in Jurupa and Rubidoux, California receive filtration at a 26-mgd regional facility located in Riverside, roughly five miles from each. For reuse-planning purposes, the conveyance routes for the effluent would be as significant as the location of the regional plant.

You should also plot sites for planned future facilities, to the extent possible. Facilities that have been designed and located from the outset with reuse in mind can prove to be less expensive in total annual costs than facilities that are designed and located simply to provide treatment and discharge.

Ideally, for the most economical wastewater reuse, wastewater-treatment facilities will be situated near an agricultural area, a park, an industry or utility, or a residential area requiring large volumes

CASE STUDY:
Tapping the Interceptor

Drawing wastewater directly from an interceptor has worked successfully since 1962 at Whittier Narrows, California in a reuse program administered by the Los Angeles County Sanitation Districts (LACSD).

Wastewater diverted from a major regional interceptor is given conventional activated-sludge secondary treatment, filtration and chlorination at the Whittier Narrows Water Reclamation Plant. The reclaimed water (along with reclaimed water from the San Jose and Pomona plants also administered by LACSD) is then applied to spreading areas for recharge of two large groundwater basins a few miles east of Los Angeles. The operation has several major attributes:

- The reclamation plant receives mostly domestic wastes. It is upstream of major industrial discharges that might make the plant's effluent unsuitable for recharge purposes.
- Sludge from the reclamation plant is diverted back to the sewer for eventual treatment downstream, serving both to reduce system complexity and costs at the upstream reclamation plant, and to improve site landscaping possibilities and, therefore, public acceptance.
- There are savings in capacity—and total costs—for conveyance and treatment facilities downstream.
- Because the plant draws a constant flow from the interceptor, its treatment performance is improved.
- In the event of a treatment-plant upset, the unsuitable effluent can be diverted back to the sewer for treatment downstream.

This system proved so successful that LACSD has since constructed four additional reclamation facilities (Pomona, Los Coyotes, Long Beach and San Jose Creek).

Source: U.S. Environmental Protection Agency Region IX and Sanitation Districts of Los Angeles County. Draft Environmental Impact Statement of Environmental Impact Report for the Joint Outfall System Facilities Plan of the Sanitation Districts of Los Angeles County, April 1976.

of water. Even if this is not the case, it is quite possible that an interceptor bearing flows to the WWTP passes through such an area. A portion of the raw-sewage flows could then be drawn off for treatment upstream of the WWTP. This kind of system can be designed to assure dependable flow of reclaimed water at the reuse sites while reducing loadings at the downstream WWTP.

Alternatively, if a long outfall (ranging from several hundred yards to several miles in length) passes through an area of potential reuse, it could prove to be relatively economical to tap the outfall for some portion or all of the treated effluent. For example, in 1978, the City of Boca Raton, Florida undertook a study to determine the feasibility of tapping its four-mile outfall in order to reclaim a portion of the secondary effluent by filtration, for use in irrigating two golf courses and a highway median strip near the outfall route.[1] By using reclaimed water for irrigation, the city hopes both to reduce demand on severely stressed potable groundwater supplies and, by reducing drawdown of the water table, to help counteract the threat of saltwater intrusion into wellfields drawing from the Biscayne Aquifer.

Where To Find Information. Information on both existing and planned facilities is usually presented in facility-planning studies carried out under Section 201 of PL 92-500, the Federal Water Pollution Control Act of 1972. If "201" studies have been completed for your municipality or region, the facility-planning report can be obtained through the responsible office of the municipality (for example, the Department of Public Works), through the state funding agency (for example, the State Department of Environmental Protection), or through the regional office of the U.S. Environmental Protection Agency (EPA).

If a facility plan has not been completed, it might be possible to obtain the necessary information from wastewater planning and feasibility studies that have been undertaken independently by the municipality. Other sources of information on wastewater-system sites and conveyance routes include area-wide water-quality management planning (commonly referred to as "208 plans") completed in your district, other regional plans, and direct contact with local, regional and state agencies responsible for wastewater management.

CASE STUDY: Reuse at Military Bases

Military bases often are ideal candidates for on-site water reclamation and reuse. Not only is there high demand for nonpotable water, but also it is relatively easy to design and implement well-controlled reuse systems that expose base personnel and the public to minimal risk. The lack of major institutional constraints means projects can be implemented more quickly than in most municipalities.

For example, the U.S. Navy has been using reclaimed water since 1977 for nonpotable domestic use at seven base housing units in Norfolk, Virginia. Treatment of secondary effluent consists of coagulant addition, sedimentation, filtration and disinfection. Reclaimed water has BOD and SS values of less than 5 mg/l and less than 10 mg/l, respectively. A 1.5 to 3.0 ppm chlorine residual is maintained in the water to maintain fecal coliform levels at zero and to provide bacteriologically safe water.

To remind customers that reclaimed water is being used and is intended for nonpotable purposes, a nontoxic, biodegradable dye is added. Even with reuse limited to toilet flushing, water savings of up to 35 percent have been achieved since instituting the project.

Another branch of the military service has initiated a larger-scale program of water reclamation and reuse that will both conserve some 500 million gallons of groundwater annually and result in life-cycle cost savings of several million dollars. At McClellan Air Force Base in California, some 1.4 mgd of reclaimed water will be used for grounds' irrigation and cooling tower make-up as well as for more specialized activities such as jet-engine test-stand cooling, acid-fume scrubbing, autoclave cooling, sand blasting and equipment washdowns. A ten-mile system of labelled pipelines will distribute reclaimed water to 40 separate user locations, and the $2.7-million project also will include a 10-mg storage reservoir and an automatic system of monitoring and alarms.

Many other military bases in the United States are presently using reclaimed water. At Fort Carson, Colorado, the Army uses a filtered secondary effluent for golf course irrigation. The Marine Corps reclaims effluent at Camp Pendleton for recharge of groundwater basins on the base. At the Air Force Academy, all effluent is used to replenish recreational lakes and to irrigate highway median strips. Other bases reportedly plan to use reclaimed water for irrigation or groundwater recharge.

The Air Force, Army and Navy have recently contracted for development of a comprehensive wastewater reuse model to aid in assessing the potential for reclamation at all fixed military facilities across the country. The model has been applied to assessments at several Air Force bases and was planned for use by the Army in 1980 for a reuse survey and preliminary design at Fort Campbell, Kentucky (Ernest V. Clements III, personal communication).

Source: Schmidt, C.J. and E.V. Clements. Total Wastewater Reuse at McClellan AFB. In: Proceedings of the Water Reuse Symposium, Vol. 1. AWWA Research Foundation, Denver, Colorado, 1979. pp. 405-420.

CHARACTERIZING SOURCES

WWTP Performance. In order to compare the quantity and quality of available reclaimed water with the requirements of potential users, you should seek out the available information on local WWTP operating performance and systematically record all pertinent information. Important to reuse planning are:

- Level of treatment (primary, secondary, advanced secondary or advanced);
- Specific processes used (activated sludge, filtration, disinfection, or nutrient reduction);
- Daily average, maximum and minimum flows, and concentrations of reported pollutants;
- Significant daily or long-term variation in quantity or quality; and
- Industrial wastewater contribution to total WWTP flow.

It might be necessary, at some point, to characterize the reclaimed-water quality in more detail, particularly for such high-level reuse as industrial process-water make-up. Some reuse entities recommend that detailed laboratory analyses, including analysis of seasonal variations in quality, be conducted as soon as possible in the planning stages, in order to eliminate this source of uncertainty. It should be noted that both EPA and the General Accounting Office have reported that more than half of the 17,000 publicly-owned WWTPs in the United States have failed to comply with treatment requirements of their NPDES permits.[2]

In some cases, however, it will be possible to establish roughly the effluent's suitability for reclamation and reuse without obtaining detailed analytical data until one or more "most-feasible" reuse alternatives will have been identified.

Water-Quality Parameters. WWTP effluent parameters that are customarily reported today are of more significance to water quality in receiving waters than they are to most reuse applications. If, for example, preservation of stream-water quality dictates the need for secondary-treatment reduction of biochemical oxygen demand (BOD) and suspended solids (SS), then only those parameters are usually reported. For most reuse applications, however, it is important to know—and, possibly, to control—levels of other classes of pollutants. Therefore, in reuse planning, it is best to consider water quality from the point of view of water supply. This approach implies that additional constraints on, for example, industrial reuse of effluent might be imposed by high levels of dissolved salts, dissolved organic material, chlorides, phosphates and ammonia nitrogen. Recreation reuse might be affected and limited by levels of turbidity, coliform counts, phosphorus and ammonia.

Substances including boron, dissolved salts and toxic residues of industrial and agricultural chemicals might restrict reuse of wastewater for agricultural purposes. On the other hand, the presence of nutrients that might have to be removed from effluents prior to discharge to receiving waters can be beneficial for some reuse applications, such as landscape or crop irrigation.

Effects of Industrial Contributions. Industrial contributions to wastewater flow can deliver toxic slugs of pollutants to a WWTP, thereby upsetting WWTP operations and effluent quality for extended periods, and can increase the proportion of non-regulated contaminants in the effluent. Wastewater from a manufacturing industry might not increase the concentrations of BOD and SS in the WWTP effluent, but might sharply elevate levels of chemical oxygen demand (COD) and total dissolved solids (TDS). While COD and TDS are parameters not normally regulated by the state or EPA for municipal secondary-treatment effluents, high levels of either could affect the success of a planned reuse program. Manufacturing industries, such as textiles and metal plating, might contribute heavy metals that render the effluent unsuitable for certain irrigation uses. You should determine what special industrial contaminants, if any, are present in the total wastewater flow. General limits for certain contaminants for selected uses are described later in this chapter. Again, the location of significant industrial sources should be plotted on your USGS map.

Effects of Flow Variation. Flow variation directly affects the marketability of reclaimed water. You should identify the flow that can be guaranteed to each user, keeping in mind that an industrial user's peak demand could be at least half again as large as its average daily demand, and an irrigation user's demand could fluctuate by a factor of 10 or 20.[3] Long-term flow variation, such as the significant reduction in wastewater flows experienced as a result of conservation measures adopted during the California drought of 1976-1977, must also be anticipated to the extent possible.

Variations in influent flow to a WWTP also affect the quality of the reclaimed-water product. Large increases in influent flows resulting from storm-related infiltration/inflow (I/I), or from slug flows from a large industrial contributor, can cause a deterioration in effluent quality. Effluent quality can also be degraded by intermittent discharges of industrial process wastes.

Examination of WWTP operating records, as discussed below, and direct conversations with other public works officials, water-district managers, or treatment plant chief operators, will help to determine if significant flow or effluent-quality variations are occurring. If they are, you might find it necessary to plan for flow-equalization storage as an element in your reuse system. Flow equalization can be provided either prior to the wastewater-treatment system or in the reclaimed-water distribution system, or both. If provided ahead of a treatment system, equalization has the added advantage of improving operation of the treatment process by permitting uniform hydraulic loading. Provision for odor control and prevention of solids' settling might be necessary, however.

Where to Find Information. Information on levels of treatment and effluent quality is available from a number of sources, as discussed in the preceding section on locating facilities. Information can also be obtained from NPDES permits for each WWTP. These permits are on file with the state or the regional EPA office, along with monthly treatment plant discharge monitoring reports on monthly maximum, average, and minimum effluent concentrations of parameters controlled by the NPDES permit.

The greatest level of detail is available from the WWTP's monthly operating records, which can usually be obtained directly from the agency operating the plant. Typical reports from a secondary wastewater treatment facility could include daily readings on flows, influent and effluent temperature, suspended solids (SS), dissolved oxygen (DO), pH, and five-day biochemical oxygen demand (BOD); effluent coliform counts and chlorine residual. If possible, hourly variations should be examined. As mentioned previously, constituents of importance to users of reclaimed water—for example, concentrations of boron—are parameters that are not monitored at most treatment plants.

Finally, on-site inspection of your area's principal treatment facilities and direct contact with treatment plant operators should be considered essential in order to put the specific effluent-quality data in context. Visits to WWTPs and interviews with plant operators will provide valuable information on plant performance, on industrial and stormwater contributions (if any) to plant flow, and on daily or long-term variations in flow. In this way, you will also establish a basis for possible future cooperative efforts with the plant staff to make your reuse plan work.

The Market for Reclaimed Water

LOCATING MARKETS

Potentially, reclaimed water will serve almost any nonpotable market currently served by freshwater supplies (Figure 2-1). In order to identify the most promising local markets for reclaimed water, you should identify the chief characteristics of all local markets for water:

- Who are the large water consumers in your municipality or district?
- Are there a few localized large consumers, or is water use characterized by widespread domestic use?
- What domestic, industrial, agricultural or recreational water users might be as well served by a reclaimed-water supply?
- What factors of water use—residential growth, irrigation needs, industrial development—are forcing your community to search for new (and increasingly expensive) sources of fresh water?

An initial listing of obvious market possibilities (the "intuitive project" referred to in Chapter 1) might include agricultural or golf course irrigation, or water for once-through power plant cooling. Such uses are relatively "low-level" and are already well-established in many areas of the United States, from Maryland to California. (Low-level uses can be defined as those uses that require only minimal additional treatment—or none at all—beyond primary or secondary treatment prior to reuse.) A closer examination might reveal other possibilities: nonpotable service to a major industrial water user or localized group of industrial users, irrigation of urban landscapes or commercial nurseries, or nonpotable water service to residences (lawn-sprinkling and toilet-flushing together constitute up to two-thirds of all domestic water use, depending on region).

Potential Markets for Reclaimed Water

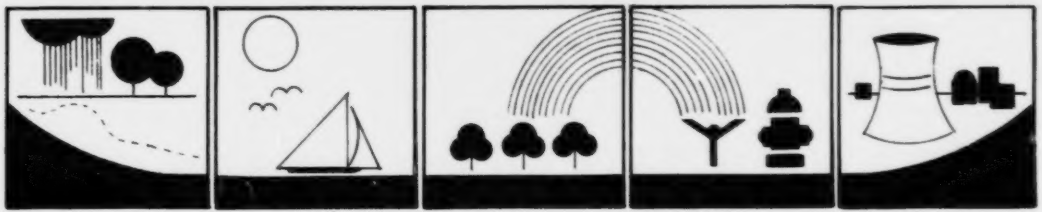


Figure 2-1. Potential markets for reclaimed water. (Source: Donovan, J.F. and J.E. Bates. Guidelines for Implementing a Municipal Program. Consulting Engineer, Vol. 53, No. 3, September 1979. pp 96-102.)

Figure 2-2 and Table 2-1 illustrate the number and variety of nonpotable reuse applications that have already been used in pilot- or full-scale installations throughout the United States. The figures used in Table 2-1 are taken from two nationwide surveys completed, respectively, in 1971[4] and 1979.[5]

The 1979 survey reported reuse projects underway in the following states:

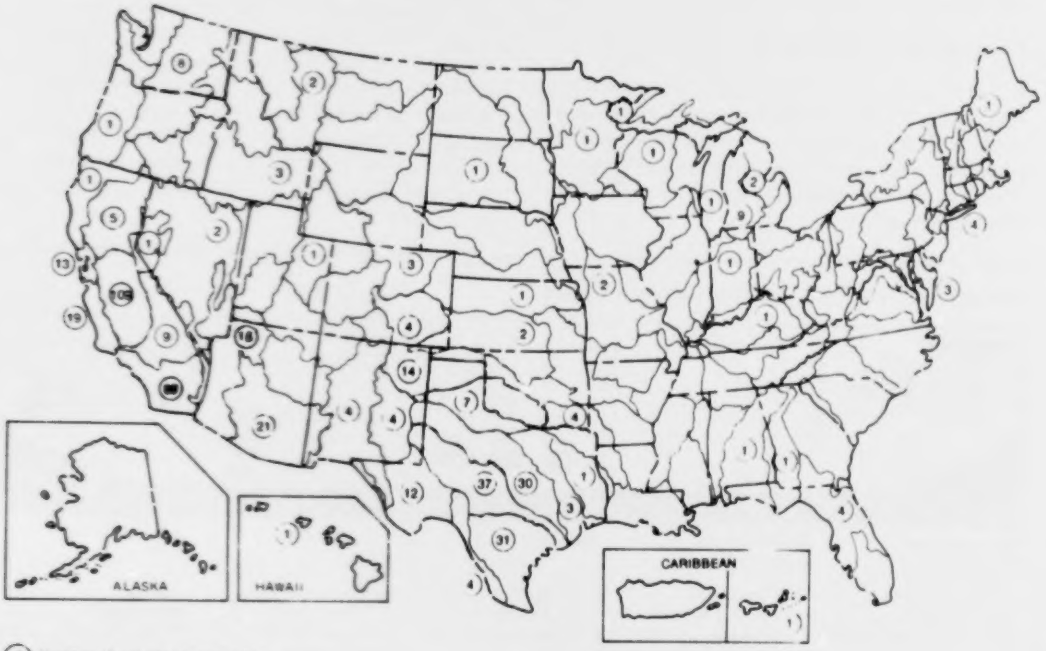
- Arizona
- California
- Colorado
- Florida
- Hawaii
- Idaho
- Indiana
- Kansas
- Kentucky
- Maine
- Maryland
- Michigan
- Minnesota
- Missouri
- Montana
- Nevada
- New Jersey
- New Mexico
- North Dakota
- Oklahoma
- Oregon
- Texas
- Utah
- Washington

and the U.S. Virgin Islands.

The California Department of Health Services in 1977-78 found reuse underway at 363 locations in the state.[6] As in the nationwide surveys, the great majority of projects—88 percent—involved types of agricultural or landscape irrigation. Another similarity among the surveys is that relatively large volumes of reclaimed water were being used for industrial and groundwater-recharge purposes (figures cited in the 1971 study included 6 mgd in Midland, Michigan; 10 mgd in Amarillo, Texas; and 120 mgd [a once-through cooling system] in Baltimore, Maryland). Most individual irrigation users were reportedly consuming only tens or hundreds of thousands of gallons per day.

Table 2-1. REUSE PROJECTS IN THE UNITED STATES

Type of Reuse	Number of Projects 1971	Number of Projects 1979
Agricultural/landscape irrigation	400	470
Industry	15	29
Groundwater recharge	10	11
Fish propagation, recreation and other	5	26
Total	**430**	**536**



(4) Number of projects in subregion.

Figure 2-2. Distribution of existing water-reuse projects in the United States. (Source: Williams, R.B. and Wesner, G.M. Recycling: An Assessment of the Potential. Consulting Engineer, Vol. 53, No. 3, September 1979. pp. 103-117.)

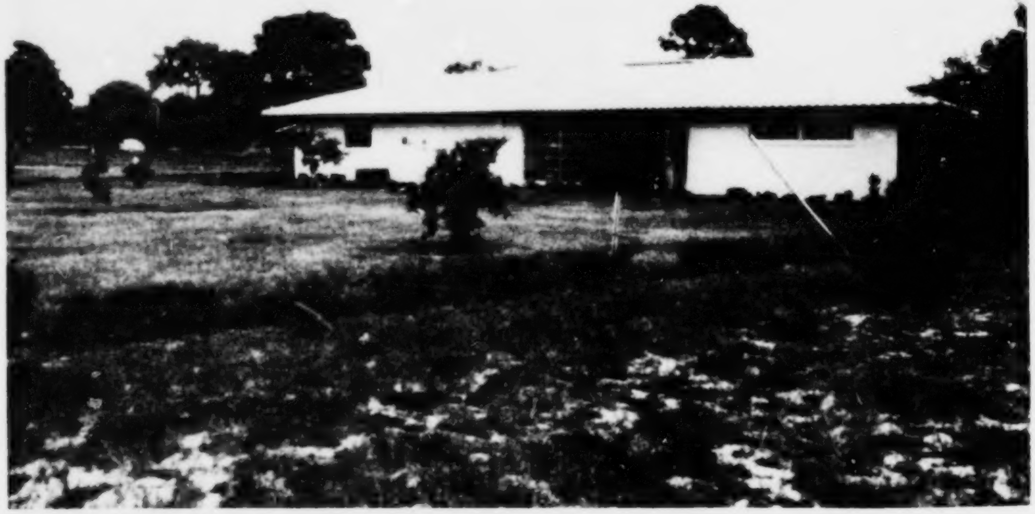


Figure 2-3. In St. Petersburg, Florida, some homeowners have elected to irrigate their lawns with reclaimed water (background) while others use the higher-priced potable water (foreground).

Nonpotable urban reuse is practiced at several locations, including the U.S. Virgin Islands, where dual systems provide some hotels and high-density residential units with toilet-flushing water, and St. Petersburg, Florida (Figure 2-3), where demand for domestic connections to an expanding nonpotable distribution system is exceeding the pace of system development.[7,8] During the drought of 1977, disinfected reclaimed water was transported and sprayed by licensed distributors to apartment complexes and single-family residences in Marin County, California, for home-landscape irrigation—the program was widely acclaimed, and it has contributed to an increasing public support there for nonpotable reuse applications.[9]

The following points should be kept in mind as you consider local reuse possibilities:

- Many reuse projects are designed for **multiple reuse applications** (Figure 2-4).
- **Not all** reuse applications listed in Figure 2-1 **are appropriate—or allowable**—in all states. Throughout the planning process, you should be identifying applicable regulations and determining how they affect implementation of reuse schemes in your area (see Chapter 4).
- **The two most important factors** in considering a potential reuser are the **volumes and costs** of its present water consumption and the **quality** of water required.

You will want to break down water consumption by user types: industrial users, commercial users, agricultural users, and estimated domestic nonpotable use. Note in particular any existing or projected locations of centralized water consumption: commercial/industrial parks, intensive housing development, agricultural lands and nurseries. Consider and locate, too, potential new uses for which freshwater supplies have not yet been tapped because of freshwater cost or availability: for example, irrigation of public lands, such as median strips and embankments of roadways; recreation facilities; cooling, etc. This information should then be plotted on the USGS map overlay.

REQUIREMENTS FOR RECLAIMED WATER

Before a potential user will seriously consider using reclaimed water, he must be assured that his requirements can be met for water quantity and quality. Cost benefits are immaterial if these basic criteria cannot be satisfied.

Sufficient water must be available when needed, whether demand is continuous (as with once-through cooling, or boiler feed), fluctuating daily (as with one-shift industries, lawn watering and nonpotable household use), or fluctuating seasonally (as with agricultural use). Provision for storage of reclaimed water can help you to meet fluctuating demand. One advantage of multiple-use projects is that they tend to serve a more uniform demand, with different user demands peaking at different times.

Figure 2-4. Reclaimed water can be used for washdown and other miscellaneous purposes—in St. Petersburg, clay tennis courts are wet down using the nonpotable supply.

Quality requirements can be satisfied in different ways. If only a single user or class of users is being served, the reclaimed-water supplier will need to meet only one level of water quality. If several types of users are being served, one approach might see all effluent reclaimed to one level, with individual users providing additional treatment as necessary; alternatively, economies-of-scale might permit the reclaimed-water purveyor to provide the quality of water required by the highest-level user so that no individual user would need to provide additional treatment.

User Water Consumption. So far, we have discussed ways to determine (1) the volume and quality of effluents available locally that might serve as a source of reclaimed water, and (2) some possible reuse markets. This section helps you to determine volume and general quality requirements of potential markets that you have identified. By comparing what is available to what is needed, you will be able to screen the potential markets in your area for those offering the best prospects for reuse, and, perhaps, to develop long-range plans for other reuse markets that do not appear to be immediately exploitable. To the extent possible, you should record the potential users' volume requirements in detail with the following considerations in mind.

Urban water demand has been examined by Deb,[10] who found that use nationally amounts to about 160 gallons per capita per day (gpcd). Table 2-2 shows the allocation of water used in U.S. communities, and Figure 2-5 illustrates national freshwater withdrawals estimated in 1975. The variations in this average water-use allocation have much to do with the economics of reuse. Where public or industrial use is proportionately higher, it is possible that the cost savings obtained through use of reclaimed water will also be proportionately higher.

In household use, exterior use (for lawn and garden irrigation, car washing, etc.) makes up from 7 to 44 percent of total average daily use, depending on season and area of the country. Of the interior urban residential demand (approximately 65 gpcd),

Table 2-2. ALLOCATION OF WATER USED IN U.S. COMMUNITIES*

Use	Percentage
Residential	40
Commercial	15
Industrial	25
Public	5
Unaccounted	15
Total	**100**

*from[10]

the proportion of various uses compared to the total interior use is shown in Table 2-3. A large portion of interior water use, such as toilet flushing, does not require potable water. (Public-health authorities have not, however, generally allowed the use of reclaimed water within the home.)

The quantity of water used for landscape or agricultural irrigation will depend on land use, climate, topography, soils, geology, hydrology, and vegetation. Annual water requirements for various common crops are presented in Table 2-4. Since irrigation water demands are seasonal in nature, the timing and magnitude of peak demands will vary widely.

In some cases, probably rarely, hydraulic loading rates might be limited by nutrient levels in the reclaimed water and by the nutrient uptake rate for the type of crop to be grown. Table 2-5 shows the nitrogen, phosphorus and potassium uptake in lb/acre-year for various forage and field crops. Based on the concentration of these constituents in the reclaimed water, the proper irrigation rate can be calculated.

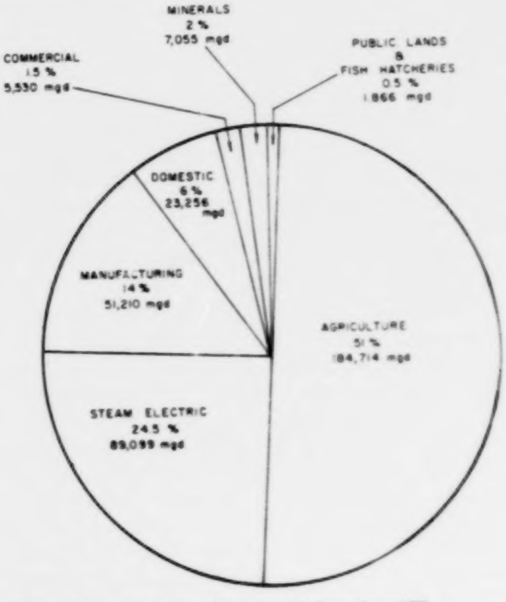


Figure 2-5. National freshwater withdrawals—1975. Agricultural irrigation constitutes the single largest demand for water in the U.S. Viewed regionally, however, irrigation is most significant in the Missouri, Arkansas and Texas regions and all states westward, while steam-electric and manufacturing water uses are more important among states east of the Mississippi. (Source: Culp/Wesner/Culp and M.V. Hughes Jr. Water Reuse and Recycling, Volume 1, Evaluation of Needs and Potential. OWRT/RU-79/1, Office of Water Research and Technology, U.S. Department of the Interior, April 1979. 173 pp.)

Table 2-3. COMPARISON OF HOUSEHOLD WATER USES*

Type of Use	% of Total Interior Use
Toilet Flushing	35-45
Bathing	25-30
Laundry	15-20
Culinary and Miscellaneous	15-20

*from[11]

Table 2-4. ANNUAL CROP WATER REQUIREMENTS*

Crop	Annual Water Requirement (feet)
Alfalfa and other forage crops, including pasture	1.0 to 6.0 or more
Potatoes, sugar beets, cotton	1.5 to 3.5
Cereals, except rice	1.0 to 2.5
Rice	4.5 to 9.5
Deciduous fruits	2.0 to 3.5
Small fruits and grapes	1.5 to 3.0
Citrus fruits	2.0 to 4.0
Walnuts and almonds	2.0 to 3.5
Vegetables, garden and truck crops	1.0 to 4.0

1 ft = 0.3 m
*from[12]

Fluctuation in Demand. For individual users, peak demand can range from 1.5 to 50 times greater than the average demand. It is essential, therefore, to evaluate peaking demand very closely in planning a reclaimed-water distribution system, particularly since the system may be serving only one or a few end users. Some users, such as one-shift industries, might require large volumes of water during relatively few hours each day, thereby placing heavy short-term demands on the supplier. Some might have storage facilities on-site to handle periods of peak demand and thus take water at a fairly steady rate. Other users, such as agricultural customers, might show seasonal variation in demand, with reduced demand (or none at all) during rainy seasons. Figure 2-6 shows a typical pattern of water use reported in the Oakland, California area for landscape irrigation at cemeteries and golf courses.

Either situation—daily or long-term variation in demand—might require that you provide for discharge to a watercourse, or another use, or storage of the excess product water (Figure 2-7). Storage is provided in impounding reservoirs at the Irvine Ranch Water District's facility in California, and is provided underground, in saline aquifers, in St. Petersburg, Florida.[5,14]

Table 2-5. NUTRIENT UPTAKE RATES FOR SELECTED CROPS*

	Uptake, lb/acre.yr		
	Nitrogen	**Phosphorus**	**Potassium**
Forage crops			
Alfalfa[a]	200-480	20-30	155-200
Bromegrass	116-200	35-50	220
Coastal Bermuda grass	350-600	30-40	200
Kentucky bluegrass	180-240	40	180
Quackgrass	210-250	27-41	245
Reed canary grass	300-400	36-40	280
Ryegrass	180-250	55-75	240-290
Sweet clover[a]	158	16	90
Tall fescue	135-290	26	267
Field crops			
Barley	63	15	20
Corn	155-172	17-25	96
Cotton	66-100	12	34
Milomaize	81	14	64
Potatoes	205	20	220-288
Soybeans[a]	94-128	11-18	29-48
Wheat	50-81	15	18-42

1 lb/acre.yr = 1.12 kg/ha.yr

*from[13]

[a] Legumes will also take nitrogen from the atmosphere and will not withstand wet conditions.

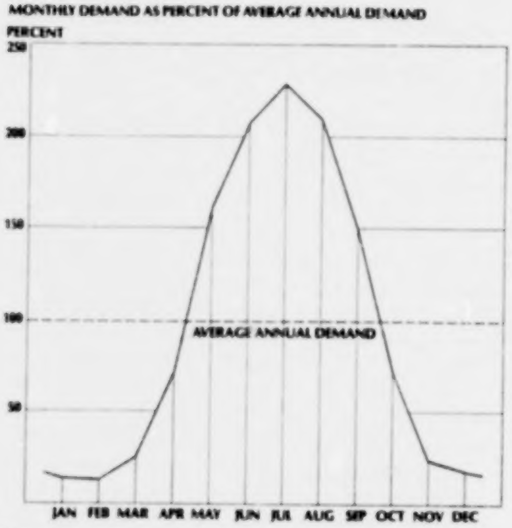


Figure 2-6. Typical pattern of irrigation water use derived from nine landscape-irrigation users in the East Bay area east of San Francisco, California. Monthly demand is shown as a percentage of average annual demand. (Source: Water Resources Planning Division, East Bay Municipal Utility District. Wastewater Reclamation: Irrigation Uses. September 1977.)

Once again, it helps to think of the reuse system as a parallel to the freshwater system. Reservoirs and storage facilities are commonly used in water systems to assure the necessary supply, in the face of fluctuating resource capacity and/or demand and, in some instances, to obtain improvements in water quality. The same benefits of storage can accrue to a reuse scheme.

Fluctuation in demand will also affect design of distribution systems. Potable-water distribution systems are usually designed to accommodate peak flows of two to five times greater than the average flow, although portions of the system may be designed with higher peaking factors, depending on the class of users being served. Distribution systems designed for fire flows can require an even greater peaking capacity: the hydraulics of fire flows are such that it is probably advisable to provide for fire flows in a reclaimed-water distribution system only if the capacity of the potable system is inadequate.

Monthly water demand in the typical municipal water system will range from 65 to 75 percent of the annual average monthly demand in the winter months, to 140 to 150 percent of the annual average monthly demand in the summer.

Where to Find Information. Water-consumption figures can be obtained from the local water-supplier's records. These records usually coincide with billing records and so may provide you with some indication of variations in seasonal demand. The responsible water-supply agency can also define for you its projections for future water use in the area.

According to some municipal entities that have explored reuse, establishing early contact with local water suppliers will stimulate their interest in reuse planning and help you to establish the project credibility that could secure the suppliers' ongoing cooperation as you approach critical stages of detailed planning and implementation. The recommended approach to these entities is "top-down:" contact suppliers first and, through them, the wholesale distributors; through the distributors, the water retailers (Wiley Horne, personal communication).

You can identify large users of water by examining consumption figures for residential complexes, for commercial, industrial and agricultural water users. In addition, lists of industries by Standard Industrial Classification (SIC) code are usually available from the public-documents section of local federal depository libraries and from the Federal Office of Management and Budget. Industries may also be listed by the municipality to which they discharge their wastes if they have adopted pretreatment or source control programs. Agricultural extension services, usually at the county level, have information on the types of crops grown in an area, the number and size of farms, water-procurement and water-quality problems, and other valuable information.

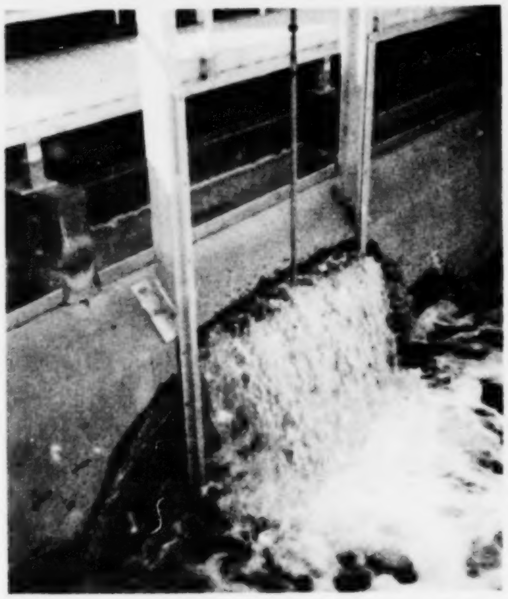


Figure 2-7. Filtered, chlorinated reclaimed water being discharged to storage reservoirs in St. Petersburg, Florida.

Actually, figures on total water consumption are useful only as background information in the preliminary stages of planning. Each potential user's total use must be broken out into potable and nonpotable subtotals, and the nonpotable use must be segregated further into that which can and cannot be supplied from a reclaimed-water project. The East Bay Municipal Utilities District (EBMUD) in Oakland, California, found in the course of its reuse investigations, for example, that potential reclaimed-water use by an industry is in general about equal to one-third of total water use by that industry (Donald Larkin, personal communication). This type of user-specific information can be obtained only by site visits and by developing with the prospective user these component estimates of demand.

For some types of users, it may be difficult to determine water consumption. Frequently, water consumption is not recorded or is reported only as a total for several individual uses or users. Additional metering or recording may be required. When users draw from private water supplies, it may only be possible to estimate water usage. Among the most comprehensive sources are certain EPA reports, such as *Quality Criteria for Water,*[15,16] and recent EPA documents developed for the implementation of industrial pretreatment requirements. Over 60 such documents are available, characterizing the wastewater for major industrial groups and subgroups and, in many cases, also discussing the volume and quality of water supplies. EPA publication 430/9-76-017c, *State and Local Pretreatment Programs*, dated January 1977, summarizes the information.[17] Any estimates you develop from using such secondary sources can be confirmed or adjusted during the initial stages of your negotiations with selected users.

For the purposes of water-reuse planning, you should attempt to examine water-consumption projections of at least 20 years ahead. Note which sources of water are currently being used, and determine which future sources of water supply will be exploited. As we have stated earlier, many communities are facing prospects of increasingly expensive water-supply development. These increased costs result because communities have already developed their nearby, and low-cost, sources of supply. New supplies must be tapped at greater distances, forcing freshwater conveyance costs up; new supplies of poorer quality might have to be used, forcing freshwater treatment costs up.

Water Quality for Reuse

RATIONALE FOR WATER-QUALITY STANDARDS

The prime water-quality objective in any reuse scheme is to prevent the spread of waterborne diseases that could occur through the use of reclaimed water. Other water-quality objectives—meeting user requirements, preventing environmental degradation, and avoiding public nuisance—must also be satisfied in developing a successful reuse program, but the starting point remains the safe delivery and use of adequately-treated reclaimed water. For nonpotable reuse, protection of public health can be achieved by (1) limiting people's exposure to the reclaimed water, and (2) reducing concentrations of pathogenic bacteria and enteric viruses in the reclaimed water. Clearly, these two methods are linked to each other. Where exposure is likely in the reuse application, effluent must be treated to a high degree prior to its reuse. Conversely, where exposure is not likely in the reuse application, a lower level of treatment may be satisfactory.

The risk of human exposure to reclaimed water—through inhalation, ingestion, or skin contact—can arise from:

- Accidental drinking of reclaimed water;
- Drinking of water that has been contaminated by reclaimed water;
- Inadvertent ingestion at a recreation area using reclaimed water;
- Frequent or long-term exposure to aerosols near spray-irrigation or cooling-tower sites;
- Working with reclaimed water;
- Eating of unwashed, raw food crops that have been irrigated with reclaimed water; or
- Eating of food crops that have been irrigated with reclaimed water containing excessive amounts of heavy metals.

With proper planning, design and management, these types of exposures can be avoided (See Figure 2-8). The State of California Department of Health Services, for example, has established guidelines for worker protection at areas using reclaimed water;[6] the guidelines are directed principally to agricultural workers exposed to reclaimed water that has received primary or secondary treatment. Some of the precautionary measures include employee

Figure 2-8. Regulation of the Irvine Ranch Water District's dual distribution system in California is permitted only for District employees or specially-trained landscape maintenance contractors.

awareness and periodic health checks, procedures to minimize direct contact or ingestion, provisions for safe potable water, and establishment of separate areas for eating. Other structural and procedural steps that can be taken to assure safe product use are addressed in the last section of this chapter, under Quality Assurance.

The development of standards for water quality criteria has evolved from an examination of health risks and optimum water quality for specific uses. At the federal level, the EPA "Blue Book"[15] and "Red Book"[16] have defined water quality requirements for specific uses. The suitability of various treatment processes for different reuse applications has been evaluated in a recent study for the Office of Water Research and Technology, U.S. Department of the Interior.[18] Outside of these documents, there exists no federal guidance or regulations defining requirements for water quality prior to multiple-purpose reuse that are comparable to those for discharge standards.

Several states have developed and issued guidance for a variety of reuse purposes; others are in the process of developing guidelines and standards. Most states have some statutes or other legal authority to control the reuse of water.

The State of California has enacted comprehensive regulations based on many years of experience and extensive health studies. Title 22, Division 4, of the California Administrative Code, enacted in 1975 and amended in 1978, addresses the use of reclaimed water. The Department of Health Services regulations establish minimum standards for bacteriological quality, treatment, and reliability for certain uses. The Department's most stringent requirements apply to (1) spray irrigation of food crops, (2) irrigation of parks, playgrounds, and schoolyards, and (3) nonrestricted body-contact recreational use. In each case, oxidation, coagulation, clarification, filtration, and disinfection (2.2 **total** coliforms/100 ml) are required, although the Department has permitted secondary treatment, coagulation, direct filtration and disinfection when the applicant has demonstrated equivalent bacterial reduction.

Not all states are this strict. For approximately the same uses as shown above, Arizona's Department of Health Services permits a far lower degree of bacteriological quality in its Title 9 Regulations. For primary contact recreation, irrigation of school grounds, playgrounds, lawns and parks, and irrigation of food crops, 200 **fecal** coliforms/100 ml are allowed. It should be noted, however, that Arizona is currently revising its Title 9 regulations and that proposed new regulations will likely be somewhat more stringent for uses that involve potential exposure of the general public.

In many states, the use of reclaimed water on parks, golf courses, and the like is not addressed at all. In the majority of these states, there has simply been no history of such projects, and approval occurs only on a case-by-case basis.

State health departments or agencies responsible for reuse activities formulate policy or decide on specific projects primarily on the basis of concerns about infectious agents, bacteria and viruses. Most other constituents in reclaimed water would pose no substantial harm in the rare instance of accidental ingestion.

Control of bacteria and their reduction in reclaimed water to low levels are processes well understood. Much less is known about treatment for removal of viruses. It is not known what concentrations of viruses are acceptable, even in potable waters. One risk of exposure to viruses in reclaimed water is associated with inhalation of aerosols from spray-irrigation units or cooling towers; this mode of transmitting viruses is recognized, but is not well understood. No widely-accepted standard techniques exist for analyzing viral concentrations in water, and the techniques that are available cannot be practiced routinely by water/wastewater agencies in most municipalities.

Therefore, the assumed correlation between removal of bacterial indicators and removal of viruses does not always hold true:

"...Low levels of viruses which may be associated with waters that meet bacterial standards may add to the viral (level) in a community, increasing the potential for virus transmission.

"Accordingly, a bacterial level and an accompanying inferred virus level that may be suitable when only a small portion of the population is exposed, such as at wastewater treatment plants or on golf courses, may not be at all adequate if the exposure is ubiquitous, as would be the case when reclaimed wastewater is distributed throughout the community."[19]

The Pomona Virus Study[20] conducted by the Los Angeles County Sanitation Districts (LACSD) showed that treatment steps of coagulation, direct filtration and two hours' chlorination on a secondary effluent "seeded" with viruses would reduce viruses by five orders of magnitude.

In another study, two principal means of disease transmission were identified: first, large-diameter (5-15μm) aerosol particles containing bacteria, which are too large to reach the lungs and are deposited in the nasopharyngeal region where they will eventually reach the stomach, and second, small ($\leq 5\mu$m) particles containing viruses, which have a fairly high chance of being inhaled and deposited in the pulmonary system.[21] A study currently underway in California might help to determine the risk of infection from aerosols generated during sprinkler irrigation with reclaimed water;[22] this field research is said to indicate that the probability of inhaling or ingesting a viable pathogen during an eight-hour exposure at a distance of 50 feet from the sprinklers is 1 in 500 million.

Clark *et al.*[23] estimated that the concentration of viruses in raw wastewater is 7,000/l, with a secondary effluent containing 10 to 50 percent of that amount. Since viruses clump together and form resistant aggregates, they are more difficult to inactivate during disinfection than are bacteria. Despite the information being gained in these and related studies, there is still lacking a "background of data of viruses in reclaimed water."[24] This lack of information, coupled with the fact that the sources of reclaimed water contain many more viruses and at higher concentrations than do the sources of potable waters, compels an increasingly conservative approach to treatment for reclamation as the degree of public exposure increases. In the determination of water-quality requirements for your project, you should first see what guidance is provided by your state. If none exists, or if there is some degree of latitude, you might present to the responsible regulating agency the guidelines promulgated by other states or the requirements that seem to fit your situation.

In the section that follows, we have discussed water-quality criteria for each of the major reuse categories: nonpotable urban, agricultural, recreational/environmental, groundwater recharge, and industrial. In each case, we have presented first, the aspects of water quality pertaining to protection of public health, and second, aspects addressing the use-specific requirements. Examples of specific water-quality requirements and guidelines are presented, based on federal and state publications and other sources in the literature.

NONPOTABLE URBAN REUSE

As shown in Figure 2-1, nonpotable urban reuse encompasses a wide variety of uses, ranging in complexity from simple golf course irrigation to dual distribution systems providing a source of nonpotable water for a number of urban uses.

Some systems of nonpotable urban reuse involve wide distribution to numerous individual users, with people in homes, factories and office buildings using reclaimed water for toilet flushing, lawn watering, area wash-ups, and even air conditioning (see Figure 2-9). Table 2-6 presents some of the major operating nonpotable urban distribution systems in the United States.

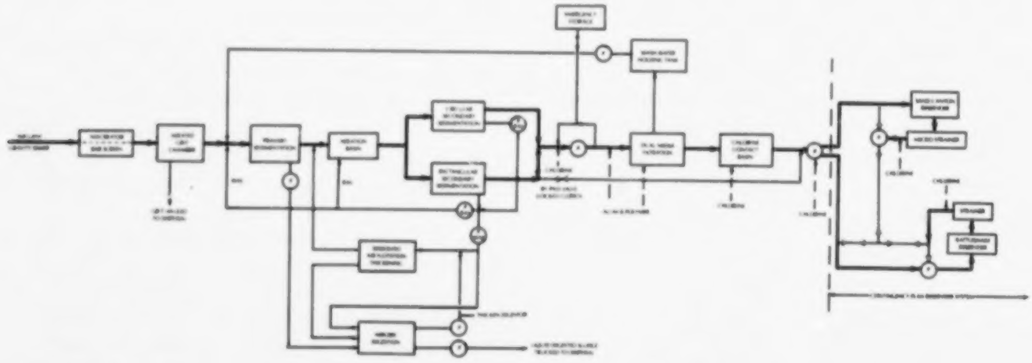


Figure 2-9. At Irvine Ranch Water District (IRWD) in California, some 5.5 mgd of filtered, disinfected secondary effluent is fed through a 50-mile reclaimed-water distribution network for use in landscape and agricultural irrigation. Eventually, IRWD will be reclaiming and distributing up to 15 mgd for nonpotable uses including expanded agricultural irrigation and, possibly, use by industries. Above, the process schematic at the Michelson Water Reclamation Plant. (Source: Zero Wastewater Discharge: IRWD's Continuing Goal. Water & Wastes Engineering, September 1978. pp. 35-37 & 148.)

CASE STUDY:
Moving Toward Nonpotable Urban Reuse in Pomona

A portion of the effluent from LACSD's Pomona Water Reclamation Plant (PWRP) has been reused for crop and pasture irrigation since 1926. In recent years, the City of Pomona Water Department also purchased secondary effluent from LACSD and resold it to a variety of private and public users for irrigation purposes. The volume of reuse increased to almost 3 mgd; the unsold portion of PWRP effluent was discharged to South San Jose Creek, where, for much of the year, it constituted the creek's only flow, and a very small portion percolated to the local groundwater basin.

Because there is frequent public contact with the water of South San Jose Creek, the Regional Water Quality Control Board (RWQCB) in the early 1970s set water-quality requirements that could be met by effluent-treatment steps of coagulation, sedimentation, filtration, and disinfection (to 2.2 coliforms/100 ml) as well as dechlorination to a 0.1 mg/l chlorine residual. The City of Pomona quickly ascertained that reuse could be greatly expanded if the RWQCB requirements were met and if there were also reduction of color to ten units or less. Potential uses included landscape irrigation for parks and institutions, process water for two paper industries, and sale to a water district and water company. The projected demand amounted to 9.5 mgd in 1977.

Cost-effectiveness analysis done on the treatment processes capable of achieving the quality requirements set by RWQCB (for discharge) and the Pomona Water Department (for reuse) showed that filtration of secondary effluent through granular activated-carbon (GAC) would meet or exceed all quality requirements at lower annual cost than the more conventional post-secondary treatment processes. Accordingly, carbon beds were constructed at the PWRP. In operation since 1977, the four carbon beds provide ten minutes of contact time at filtration rates of 3.5 gal/min/s.f. The system can be run as a one-stage carbon-adsorption step with sulfur-dioxide dechlorination at 10 mgd or as a two-stage system providing carbon-adsorption/dechlorination at 5 mgd.

Present users include the Pomona City Parks Department, Los Angeles County Regional Park and Golf Course, a county landfill, the state Department of Transportation, a state college farm, California State Polytechnic University and a paper processing company. Negotiations are being completed with potential additional users, including a cemetery, another paper company and Mt. San Antonio College. Currently, all direct reuse is for landscape and agricultural irrigation and paper pulp processing.

Reclaimed water from the Pomona plant achieves the following levels: SS, 1 mg/l; BOD5, 2 mg/l; coliforms, 2 MPN/100 ml; residual chlorine, 0.1 mg/l; turbidity, 1.4 NTU; color, 7 color units.

Source: Garrison, W.E., J.E. Gratteau, B.E. Hansen and R.F. Luthy. Gravity Carbon Filtration to Meet Reuse Requirements. Journal of the Environmental Engineering Division, ASCE, December 1978. pp. 1165-1174.

Table 2-6. NONPOTABLE URBAN REUSE SYSTEMS

Location	Date of Initial Operation
Grand Canyon Village, Arizona	1926
Colorado Springs, Colorado	1960
Irvine Ranch Water District, California	1975
St. Petersburg, Florida	1977
Santa Margarita Water District, California	1979

Several other systems are now in the planning stages. For example, the Walnut Valley (California) Water District recently completed a feasibility study on a $5.6-million distribution network for delivering low-cost reclaimed water to 21 points of use.[25] The District will purchase reclaimed water from the City of Pomona Water Department (which obtains effluent from the Pomona Water Reclamation Plant, owned and operated by the Los Angeles County Sanitation Districts) and will sell it to retail water agencies in the District. All reuse-system facilities will be owned and operated by the District, while the retail agencies will manage sales and customer service. The State of California has also recently approved plans for a system in which reclaimed water would be directly available for purchase by individual homeowners; the proposed system is located in Las Virgenes.

Despite the growing interest in nonpotable urban reuse systems, there are currently few legal or governmental standards regulating reclaimed-water quality for this purpose, although some state guidelines address many of the specific uses that fall under this category. California's Title 22 reclamation criteria range from use of oxidized, disinfected effluent meeting a concentration of 23 coliforms/ 100 ml for urban-landscape irrigation, to use of an oxidized, coagulated, clarified, filtered, disinfected effluent meeting a concentration of 2.2 coliforms/ 100 ml for irrigation of parks, playgrounds, and schoolyards.

The California standards fail to address some areas of nonpotable urban reuse, such as toilet flushing. A reuse program in Las Virgenes that had proposed use of reclaimed water for lawn watering and toilet flushing has so far been limited to the former use only, for this very reason. Some prospective users hope, however, that the program will be expanded to include toilet flushing, if agreement can be reached on what quality standards are necessary for nonpotable reuse in the home.[26]

Several states (Michigan, Nevada, Pennsylvania, South Dakota, and Texas) prohibit the use of reclaimed water on parks or playgrounds. Georgia's "Criteria for Wastewater Treatment by Spray Irrigation" (Department of Natural Resources, July 1978), calls for secondary treatment and disinfection for landscape irrigation of golf courses, cemeteries, public parks and "other areas frequently visited by the public." The disinfection system must be designed to reduce fecal coliform concentrations to a maximum count of 30/100 ml. Irrigation must also be restricted to hours when irrigated areas are not normally used by the public.

The State of Florida Department of Environmental Regulation has proposed rules for reuse. Section 111A (drafted in 1976) governs nonpotable urban uses such as spray irrigation of golf courses, cemeteries, public parks, landscaped areas and "other areas with access to the public." In these areas, a secondary effluent with turbidity levels of less than 5 Jackson Turbidity Units (JTUs) before disinfection may be applied to land. Disinfection should be designed to produce a median (seven-day) number of coliform organisms not exceeding 2.2/100 ml, and the number in any one sample should not exceed 23/100 ml. The reclaimed water must be stored for a minimum of three days and may be used only during hours when the public does not have access or is unlikely to be present. Chapter 17-6 of the Florida Administrative Code, which will include reuse, is currently being revised.

In Utah, advanced wastewater treatment (BOD, 10 mg/l; SS, 5 mg/l) and disinfection (3 coliforms/ 100 ml) are required prior to nonpotable urban reuse. These standards, contained in Part II of the Division of Health "Wastewater Disposal Regulations," apply to irrigation of public areas as well as to use in industrial areas where workers may be exposed.

As mentioned earlier, some states have provided more lenient standards of water quality prior to reuse. The Texas Department of Health has published "Recommended Practices for Irrigating Controlled Public Access Areas with Treated Domestic Wastewater." The 1976 guidelines call for treatment to reduce BOD and SS concentrations to 20 mg/l and coliforms to 200/100 ml. Texas is the only state that requires disinfection to maintain a trace chlorine residual at the sprinkler heads. Arizona's regulations are very liberal compared to those in its neighboring state of California. For irrigation of golf courses, cemeteries and other similar areas, a disinfected secondary effluent may contain a monthly average of 5,000 total coliforms/ 100 ml and 1,000 fecal coliforms/100 ml. Similar reuse projects in California permit no more than 23 total coliforms/100 ml.

For irrigation of school grounds, playgrounds, lawns, parks, or "any other areas where children are expected to congregate or play," more stringent requirements must be met in Arizona. The wastewater must undergo tertiary treatment and disinfection to reduce BOD to 10 mg/l, SS to 10 mg/l, and fecal coliform concentrations to 200/100 ml. Again, for comparison, similar projects in California are required to achieve 2.2 **total** coliform/100 ml.

The Arizona regulations were first drafted in 1972 and are currently being revised (M. Matters, personal communication). Bacteriological standards will probably be tightened for urban uses. Agricultural irrigation will be encouraged. This situation is typical in many states, as agencies respond to new information, or restructured government agencies change state reuse philosophies, or simply as agencies periodically review and update their existing regulations. It is best to check frequently with the appropriate state agency throughout your reuse planning.

CASE STUDY:
Agricultural Reuse in Tuolumne County

The Tuolumne County Water District No. 2 (TCWD No. 2) faced a dilemma in trying to find an acceptable method for disposing of effluent from two 1-mgd treatment plants in its jurisdiction. Stream discharge of the plants' effluent was prohibited by California regulations enacted in 1971, and a land-application disposal alternative proposed in 1972 was met by hostile public reaction.

In an attempt to identify a workable program, the County, which is located southeast of San Francisco, moved in 1975 to engage a consultant. The consultant recommended winter storage of effluent with delivery as irrigation water in season to individual ranchers. Although the new plan eliminated the wide-scale land-application system that had raised so many objections in 1972-1973, TCWD No. 2 representatives and consultants found it necessary to meet regularly with opponents of the new plan over a one-year period before a level of public confidence and support was achieved.

The $4-million irrigation plan, as adopted, will serve over 30 area ranches with secondary effluent suitable for irrigation of some 1,300 acres of pastureland, meeting all state Department of Health Services water-quality criteria for this purpose. Flow rates for each rancher are adjustable and range from 100 gpm to 1,300 gpm. They can be controlled remotely, at the treatment plant, to conform to predetermined demand schedules. The system is unusual in that it operates as a true irrigation system rather than as an effluent-disposal system. Project elements of particular interest include:

- **Storage/Conveyance Facilities:** a nine-mile asbestos cement effluent-outfall/transmission pipeline of 6- to 24-inch diameter, an 1,800-acre-foot irrigation storage reservoir, and a 15-hp pumping plant.
- **Automated Control and Monitoring:** a computer-based system (1) to monitor status and flow, (2) to provide remote control of solenoid-actuated globe valves to each irrigation turnout, and (3) to control a 16-inch throttling valve just upstream of the storage reservoir (to maintain full-pipe flow conditions and fairly constant pressure at the turnouts).
- **Contractual Arrangements:** individual 20- to 40-year contracts with each rancher for specified quantities of water to be delivered during the April-through-October irrigation season. Signing of the contract obligates the rancher to accept the water delivered at no charge.
- **Water Delivery Schedule:** based on yearly negotiations with ranchers, effluent quantities in storage before the start of irrigation, estimates of summer wastewater flow, and ranchers' acreage and crops.

The system was operated on a reduced-scale, non-automated basis in 1978 and 1979, with fully-automated delivery of effluent to begin in 1980.

Source: Earles, J.D. and L.C. Amans. Irrigating Private Land with Wastewater Effluent. In: Proceedings of the Water Reuse Symposium, Vol. 3. AWWA Research Foundation, Denver, Colorado, 1979. pp. 2046-2053.

Some have suggested that nonpotable urban distribution systems should meet the same bacteriological and turbidity requirements as are set forth in the present EPA standards for drinking water: an average of 1 total coliform/100 ml and 1 (or up to 5) turbidity unit(s), respectively (Daniel A. Okun, personal communication). The Interim Primary Drinking Water Standards of the Safe Drinking Water Act (PL 93-523) call for a maximum level of turbidity of 1 turbidity unit (TU) as a monthly average. Up to 5 TUs are permitted if the supplier of water can demonstrate that the higher turbidity does not:

- interfere with disinfection,
- prevent maintenance of an effective disinfecting agent throughout the distribution system, or
- interfere with detection or analysis of microorganisms.

You will note that the treatment requirements of the various states are not directed toward removal of nutrients; most nonpotable urban systems use reclaimed water extensively for landscape irrigation, where the nutrients are of distinct benefit.

AGRICULTURAL REUSE

These fundamental criteria shape the quality requirements for use of reclaimed water in agricultural irrigation:

- For the protection of farmworkers and the general public, the use of reclaimed water must pose no bacteriological or **virological** hazard.
- In the West, salinity (total dissolved solids, or TDS) must be low enough to maintain favorable osmotic pressures for plants to take up water.
- Certain ions making up TDS, such as boron, chlorides and sodium, are specifically harmful to some crops; a high level of sodium can also be harmful to soils.
- Trace levels of certain metals and synthetic organics can affect crop growth. Obviously, even very low concentrations of herbicides can be toxic to plant life.
- Other heavy metals, such as molybdenum and, possibly, cadmium, can be concentrated by plants to levels high enough to be toxic to animals eating the plant (which itself might be unaffected by the substance).
- Return flows from both surface and subsurface irrigation are non-point sources of pollutants and either are, or soon will be, subject to control. The quality requirements that are imposed on irrigation return flows may dictate a high quality of the applied water.
- Suspended solids, chemical precipitates and algae growth can clog the spray nozzles and drip applicators of irrigation units.

No agency has established with certainty what pollutant parameters are hazardous or toxic at what levels. And many of the pollutants present in effluent are present also in other sources of irrigation water, including irrigation canals passing through farmlands.

In these *Guidelines*, we recommend that the quality of reclaimed water be analyzed for the constituents that might affect your ability to use the resource in irrigation. Table 2-7 presents the recommended EPA limits for pollutants in irrigation water. The recommended maximum concentrations for "long-term continuous use on all soils" are set conservatively, to include sandy soils that have low capacity to react with (and so to sequester or remove) the element in question. These maxima are below the concentrations that produce toxicity when the most sensitive plants are grown in nutrient solutions or sand cultures to which the pollutant has been added. The criteria for short-term use (up to 20 years) are recommended for fine-textured neutral and alkaline soils with high capacities to remove the different pollutant elements.

Bacteriological Quality. Several states address bacteriological standards in their regulations. The California standards require different bacteriological standards for each of three types of agricultural uses. For fodder, fiber and seed crop, and for orchards and vineyards where only surface irrigation is used, a primary-treated effluent is allowed. Primary effluent would be expected to contain about 5×10^5 to 5×10^7 total coliforms/100 ml, depending on the raw wastewater characteristics. For irrigation of pasture for milking animals, and for food crops where surface irrigation only is practiced, an oxidized, disinfected effluent is required. The bacteriological standard calls for no more than 23 coliform organisms/100 ml as a median during a seven-day period.

Bacteriological standards in California are most stringent when reclaimed water is sprayed on food crops. Again, a major concern is the health of farmworkers. Only 2.2 coliforms/100 ml as a weekly median count is allowed, following the treatment train of oxidation, coagulation, clarification, filtration, and disinfection.

Like California, the State of Arizona Department of Health Services requires various levels of bacteriological removal for various types of agricultural reuse. For irrigation of fibrous or forage crops not intended for human consumption, or for irrigation of orchard crops by methods that do not result in direct application of water to fruit or foliage, secondary treatment is required. Secondary treatment is capable of removing from 90 to 99 percent of total coliform indicator organisms. Approximately 1×10^4 to 1×10^7 coliforms/100 ml would be expected in the reclaimed water.

Secondary treatment and disinfection are required in Arizona for irrigation of orchard crops where fruit or foliage comes into direct contact with reclaimed water and for irrigation of food crops if the product, in either case, is subject to physical or chemical processing sufficient to destroy pathogenic organisms. The disinfection step should be designed to result in a monthly average of 5,000 total coliforms/100 ml and 1,000 fecal coliforms/100 ml.

Table 2-7. RECOMMENDED LIMITS FOR POLLUTANTS IN RECLAIMED WATER USED FOR IRRIGATION*

TRACE HEAVY METALS

Constituent	Long-Term Use[a] (mg/l)	Short-Term Use[b] (mg/l)	Remarks
Aluminum	5.0	20.0	Can cause non-productivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity.
Arsenic	0.10	2.0	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Beryllium	0.10	0.5	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Boron	0.75	2.0	Essential to plant growth, with optimum yields for many obtained at a few-tenths mg/l in nutrient solutions. Toxic to many sensitive plants (e.g., citrus plants) at 1 mg/l.
Cadmium	0.01	0.05	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solution. Conservative limits recommended.
Chromium	0.1	1.0	Not generally recognized as essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants.
Cobalt	0.05	5.0	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Copper	0.2	5.0	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solution.
Fluoride	1.0	15.0	Inactivated by neutral and alkaline soils.
Iron	5.0	20.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybdendum.
Lead	5.0	10.0	Can inhibit plant cell growth at very high concentrations.
Lithium	2.5	2.5	Tolerated by most crops at up to 5 mg/l; mobile in soil. Toxic to citrus at low doses—recommended limit is 0.075 mg/l.
Manganese	0.2	10.0	Toxic to a number of crops at a few-tenths to a few mg/l in acid soils.
Molybdenum	0.01	0.05	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.
Nickel	0.2	2.0	Toxic to a number of plants at 0.5 to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Selenium	0.02	0.02	Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of added selenium.
Tin, Tungsten and Titanium	–	–	Effectively excluded by plants; specific tolerance levels unknown.
Vanadium	0.1	1.0	Toxic to many plants at relatively low concentrations.
Zinc	2.0	10.0	Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils.

Table 2-7. (Continued)
OTHER CONSTITUENTS

Constituent	Recommended Limit	Remarks
pH	4.5-9.0	Most effects of pH on plant growth are indirect (e.g., pH effects on heavy metals' toxicity described above).
Fecal Coliform Density	1,000/100 ml	Irrigation waters at or below this limit should pose no hazard to animals or man from their use or from consumption of raw crops irrigated with the waters.
TDS	500-5,000 mg/l	Below 500 mg/l, no detrimental effects are usually noticed. Between 500 and 1,000 mg/l, TDS in irrigation water can affect sensitive plants. At 1000 to 2000 mg/l, TDS levels can affect many crops, and careful management practices should be followed. Above 2,000 mg/l, water can be used regularly only for tolerant plants on permeable soils.

[a] For water used continuously on all soils.
[b] For water used for a peroid of up to 20 years on fine-textured neutral or alkaline soils.
*from[15]

In many states, bacteriological standards are applied on a case-by-case basis. In Georgia, for example, all domestic wastewater must receive biological treatment prior to irrigation. Disinfection is usually not required, however, unless it is deemed necessary "to protect the health of persons contacting the wastewater or the vegetation on which it is sprayed, or to reduce odor potential." If disinfection is required, it must be designed to reduce fecal coliform to a maximum of 200/100 ml.

In Florida, most agricultural reuse projects are required to provide secondary treatment and disinfection to reduce total coliforms to a seven-day median of 23/100 ml. This applies to sod farms, forests, and fodder crops, as well as pasture lands (Figure 2-10). Additionally, dairy cattle may not graze until 15 days after irrigation. The use of reclaimed water for crops intended for human consumption is prohibited in Florida.

Many states have no experience with the use of reclaimed water for agricultural reuse. In these states, usually, the better-controlled the agricultural operation is, the less the degree of treatment that will be required.

Salinity. Total dissolved solids (TDS) in the reclaimed water alter the osmotic state of water in the soil. When concentrations of TDS become high, plants can wilt even when fields have been watered. This problem is of special concern in western states.

Since the TDS of secondary effluent is typically higher than that of freshwater supplies, control of salinity can be an important criterion in agricultural-irrigation reuse systems. The TDS of the reclaimed water will depend principally on the source and characteristics of the potable water supply. Where TDS is high, the problem is aggravated by poor leaching characteristics in the soil, by high evapotranspiration rates, and by the type of crop being irrigated—avocado, berry and citrus crops are much more sensitive than pasture or landscape grasses, for example. Through proper planning, the problem can be minimized by assigning reclaimed water to irrigation of non-sensitive crops, and by practicing proper irrigation management. Drip-irrigation methods permit use of water with somewhat higher TDS than what can be used for spray irrigation, because in spray irrigation the higher salt concentration could damage foliage. Increased leaching will help to flush out excess salts in the soil, but at the risk of polluting groundwater. If the irrigation value of reclaimed water is high enough in your area, methods of demineralization, such as reverse osmosis, can reduce TDS levels while retaining inorganic nitrogen as a nutrient in the water.

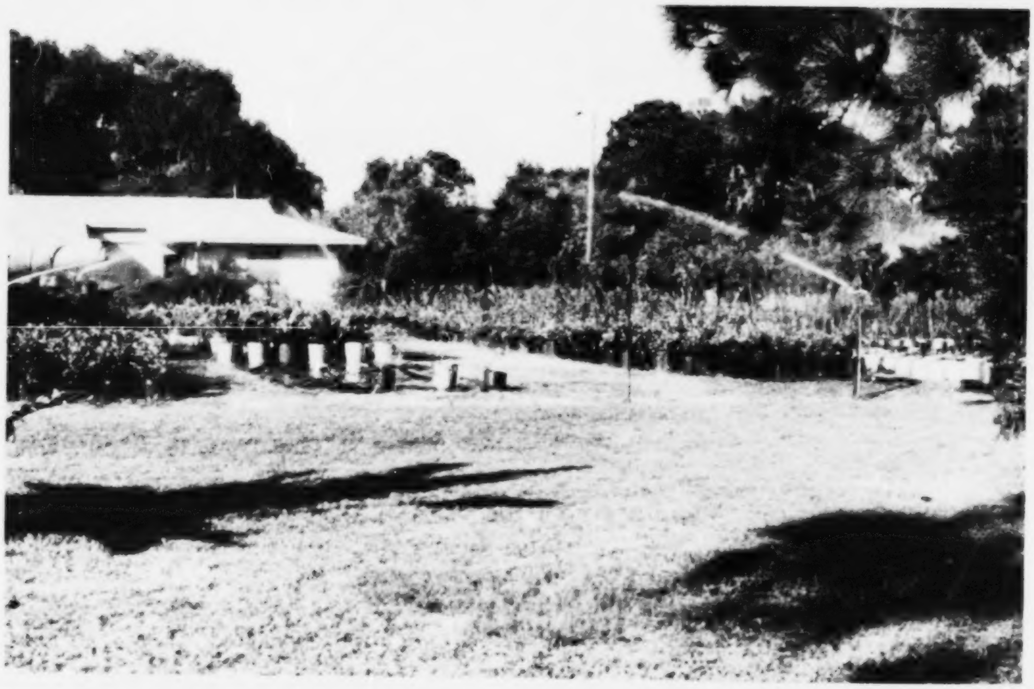


Figure 2-10. A municipal nursery in St. Petersburg, Florida waters its stock with reclaimed water.

Specific Ions. Chlorides, boron and sodium are ions among the total dissolved solids that can have specific harmful effects on certain crops. If any of these ions is present in high concentration, the crops might exhibit wilting, leaf drop and reduced crop yield, even if TDS is below levels considered harmful. Again, fruit crops are more sensitive to these substances than are many other crops. Slightly increased soil fertility and more frequent irrigation can help to minimize the effect of these ions. Excess sodium not only directly affects plant growth, but also can alter soil structure so as to make it unsuitable for efficient irrigation.

Heavy Metals. The effects of heavy metals vary with pH and physical characteristics of the soil and with type of crops being irrigated. As shown in Table 2-7, arsenic, cadmium, copper and nickel are among the heavy metals that are toxic to some crops. The chemistry of heavy metals in the soil, their accumulation in plants, and their toxic effects on plants and animals are not yet well understood, and it is for these reasons that conservative limits are recommended. Once these metals have accumulated in the soil, they are difficult to remove.

RECREATIONAL AND ENVIRONMENTAL REUSE

Uses of reclaimed water for recreational and environmental purposes range from the maintenance of landscape ponds, such as water hazards on golf course fairways (Figures 2-12 and 2-13), to full-scale development of water-based recreational sites for swimming, fishing, and boating. In between lies a gamut of possibilities that includes use in fountains, snowmaking, rearing of freshwater sport fish, and the creation of marshlands to serve as wildlife habitats and game preserves.

California's recommended treatment train for each type of recreational water reuse is linked to the degree of body contact in that use (that is, to what degree swimming and wading are likely). Secondary treatment and disinfection (to 23 coliforms/100 ml) is required for reuse in landscape ponds. More stringent disinfection, to 2.2 coliforms/100 ml, is required for recreational water bodies where fishing and boating are permitted. And, for nonrestricted recreational use that includes wading and swimming, treatment of secondary effluent is to be followed by coagulation, filtration and disinfection to

CASE STUDY:
Irrigation and Reuse in Westminster

Close cooperation between the City of Westminster, Colorado and a local farmers' company led to development of a reuse plan that benefits both parties.

Finding itself pressed by competing needs to supplement the city's water supply and to meet stringent new wastewater treatment requirements, Westminster in 1976 negotiated an agreement for exchange of water with the Farmers' High Line Canal and Reservoir Company, one of many Colorado farmers' organizations to which water rights are assigned for irrigation. The agreement enables the city to withdraw water from the company's canal, transfer it to a city reservoir, and use it in the City's potable-water treatment and distribution system. In turn, the city returns to the canal an amount of reclaimed water equal to the original withdrawal. The canal water is subsequently used for irrigation by members of the farmers' company (Figure 2-11).

The agreement provides Westminster with an expanded water supply, one that can meet its projected needs for the next 20 years. It also benefits the farmers. In returning to the canal an amount of water equal to that withdrawn some distance upstream, the city actually increases the canal flow by making up the "ditch loss"—an amount of water estimated at 20 percent of total flow that would otherwise have been lost in flow between the points of withdrawal and return. The nutritive content of the reclaimed water also improves crop growth.

Regulation has not been restrictive. Quality requirements are stipulated by the State Department of Agriculture standards for irrigation water and by NPDES discharge standards. The canal water augmented with reclaimed water meets all of the state's standards and is considered suitable for unrestricted irrigation use. The farmers themselves are exceptionally efficient in controlling runoff from the fields; runoff is diverted to other fields and other farmers. No exchange of money is involved, nor is there any limit on the amount the city can withdraw from the canal (provided, of course, that an equal amount is returned).

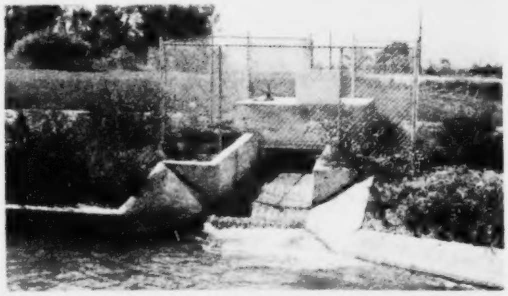


Figure 2-11. Reclaimed water from City of Westminster, Colorado secondary treatment facilities is discharged to the Farmers' High Line Canal; upstream, the City has withdrawn an equal amount of fresh water from the canal. (Photo courtesy of Robert L. Ferguson, Director, Department of Operational Services, City of Westminster.)

In developing the project, the city dealt directly with the farmers' company. The state and EPA were involved because an NPDES permit was required in order to discharge the reclaimed water to the canal, and because the state administered the Clean Water Act funds that were used to build the new treatment plant, reclamation facilities and pump station and force main for conveyance of reclaimed water to the canal. Also, as the land-application aspects of this reuse plan satisfied the state's policy on discharge, Westminster obtained a favorable position on the state's funding-priorities list. The local share of the funds was raised through tap fees and utility bond sales.

Source: Thurber, M.D. Vision of Balance. In: Proceedings of the Water Reuse Symposium, Vol. 3. AWWA Research Foundation, Denver, Colorado, 1979. pp. 2054-2059.

achieve 2.2 coliforms/100 ml and a maximum of 23 coliforms/100 ml in any one sample taken during a 30-day period. The primary purpose of the coagulation step is to reduce suspended solids and, thereby, to improve the efficiency of virus removal by chlorination.

The State of Arizona also regulates the use of reclaimed water in recreational impoundments, and is currently reviewing its regulations. All reclaimed water is required to receive secondary treatment and disinfection prior to its use in any impoundment used for aesthetic enjoyment or for purposes involving only "secondary contact recreation." Monthly average total and fecal coliform densities of 5,000/100 ml and 1,000/100 ml, respectively, cannot be exceeded. For any impoundment used for primary contact recreation, the bacterial standards are 200 fecal coliforms/100 ml.

Figure 2-12. Pumping of reclaimed water to golf course water hazards can fulfill a recreational need while also providing storage or "polishing" treatment for the reclaimed-water supply. Above, at Irvine Ranch Water District in California . . .

Figure 2-13. . . . and at St. Petersburg in Florida.

CASE STUDY:
Reuse for Marshland Reclamation

Two projects northeast of San Francisco have shown that secondary effluent can be used effectively to create or reclaim marshlands that serve as valuable wildlife havens. Moreover, effluent discharged into these managed marshlands receives the equivalent of "tertiary" treatment through natural physical and biological processes in the marsh.

The Mt. View Sanitary District of Contra Costa County has been applying some 0.6 mgd of "30/30" effluent to low saline land draining into Suisun Bay for more than four years. The flooded marshland area has attracted over 93 species of waterfowl shorebirds and passerine birds, including both migratory ducks—ruddy ducks and canvasbacks, for example—and resident species such as four generations of cinnamon teal that have lived and bred exclusively in the created wetland system. Some 68 species of plants have been counted in the multiple-habitat system which includes areas of open water and vegetated shallows. And at least 34 species of aquatic invertebrates populate the marsh, which is surrounded by large oil and chemical installations and a freeway. District personnel view the numbers and diversity of marsh wildlife forms as a clear indication of the system's vigor.

Based on early results obtained in weekly monitoring and analysis, the original eight-acre marshland has been expanded to 21 acres, of which 18 are kept flooded (Figure 2-14). The varying depth of water attracts different species of wildlife and also helps to control the spread and dominance of any single type of vegetation. The District removes excess vegetation by mechanical and manual means. Problem-causing species of algae—the bluegreen, filamentous and odor-producing types—have not thrived in the managed system; and the common marsh nuisance of mosquitos has been effectively eliminated by open-air circulation patterns and the stocking of predatory mosquitofish, *Gambusia afinis*.

The system provides additional treatment of secondary effluent by seasonally reducing effluent BOD and SS and by removing nitrates and residual chlorine year-round. The wildlife habitat has proved to be of great interest to school groups, nature photographers and bird watchers, who, in 1978, spent some 854 personhours visiting the wetlands area and the small environmental center maintained there by the District.

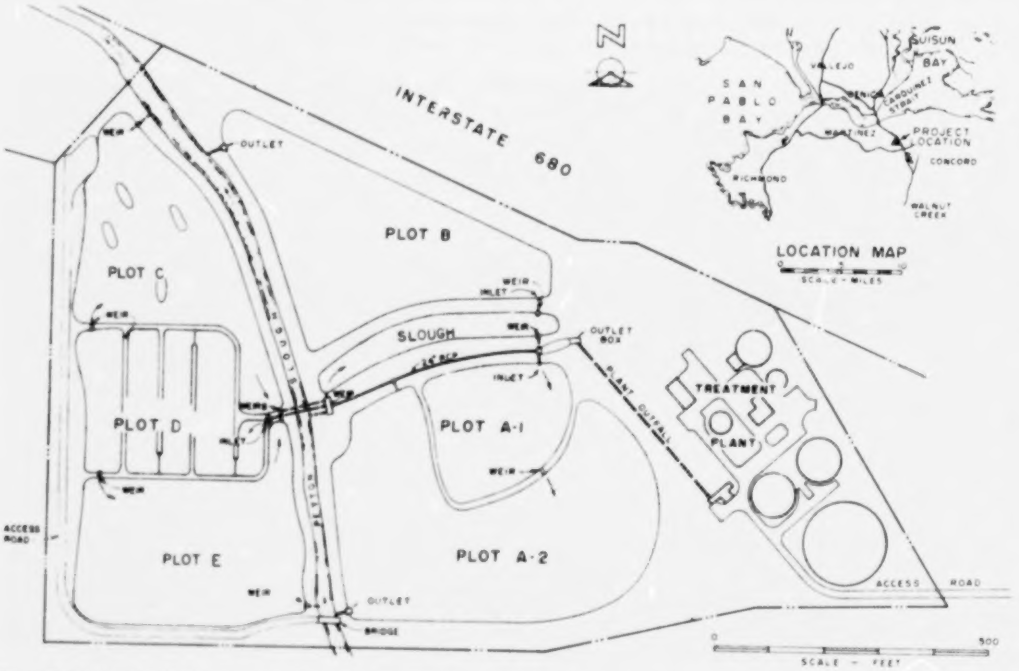


Figure 2-14. Wetlands plot plan, Mt. View Sanitary District's marsh enhancement program. Secondary treatment plant effluent flows by gravity into Plot D. After approximately ten days' retention in the wetlands system, the marsh waters are discharged from Plots A-2 and B into Peyton Slough.

Projected costs for Mt. View to join regional collection/treatment systems had ranged from $2.5 to $6 million. The expanded 21-acre marsh system, as an alternative, cost $96,000 to develop, and has present operations-and-maintenance costs of $12,000 per year. Due to the system's gravity flow, it bears no pumping costs.

Similar success was obtained in the U.S. Bureau of Reclamation's Suisun Marsh management program, carried out over a three-year period in cooperation with the City of Fairfield and the Solano Irrigation District. The 55,000-acre leveled marsh is located midway between San Francisco and Sacramento and is important to the Pacific Flyway, supporting a half-million or more waterfowl that nest and feed there in the wintertime.

From 1975 to 1978, BUREC distributed some 0.25 mgd of filtered effluent from aerated oxidation ponds to pilot-scale field facilities in the marsh area, including a three-acre sprinkler-irrigated tile-drained pasture, marsh ponds of two to three feet in depth, and two flooded marshland areas of 1½ acres each (Figure 2-15). Monitoring of effluent quality and its effects during this period showed that levels of inorganic nitrogen and phosphorus could be reduced to less than 1 mg/l each in pasture irrigation and to about 3 mg/l or less each in the flood ponds. Tile-drained pasture return flows showed a gradual decrease in soil salinity from 25,000 mg/l TDS to less than 9,000 mg/l as soil salts were leached out during effluent applications of up to 12 inches of wastewater per month. The only problem encountered was in the permanently flooded ponds, where filamentous-algae growth was excessive in summer months. In future operation, the ponds will be maintained at five- to six-foot depths to avoid this problem.

Major benefits of the pilot program proved to be the improved quality of effluent and the good growths of bulrush—a waterfowl forage grass—in the seasonally-flooded shallow marsh ponds. The Bureau noted a significant compatibility between reuse for agricultural irrigation, which peaks in summer, and for marshland flooding, which peaks in winter.

On the basis of the pilot study, the program was expanded in 1978 to a five-year study of marsh flooding for three nearby duck clubs, now using effluent from the newly-completed 10-mgd Fairfield subregional treatment plant. The clubs are flooding about 650 acres of marshland. The improved bulrush stands resulting from irrigation with effluent have brought about a change in the duck club members' attitudes from one of skepticism to interest and enthusiastic support. It is expected that other clubs will soon be joining the marsh reclamation effort.

Sources: Demgen, F.C. and J.W. Nute. Wetlands Creation Using Secondary Treated Wastewater. In: Proceedings of the Water Reuse Symposium, Vol. 1. AWWA Research Foundation, Denver, Colorado, 1979. pp. 727-739.

Roche, W.M. and N. Cederquist. Reclamation and Reuse of Wastewater in the Suisun Marsh, California. In: Proceedings of the Water Reuse Symposium, Vol. 1. AWWA Research Foundation, Denver, Colorado, 1979. pp. 685-704.

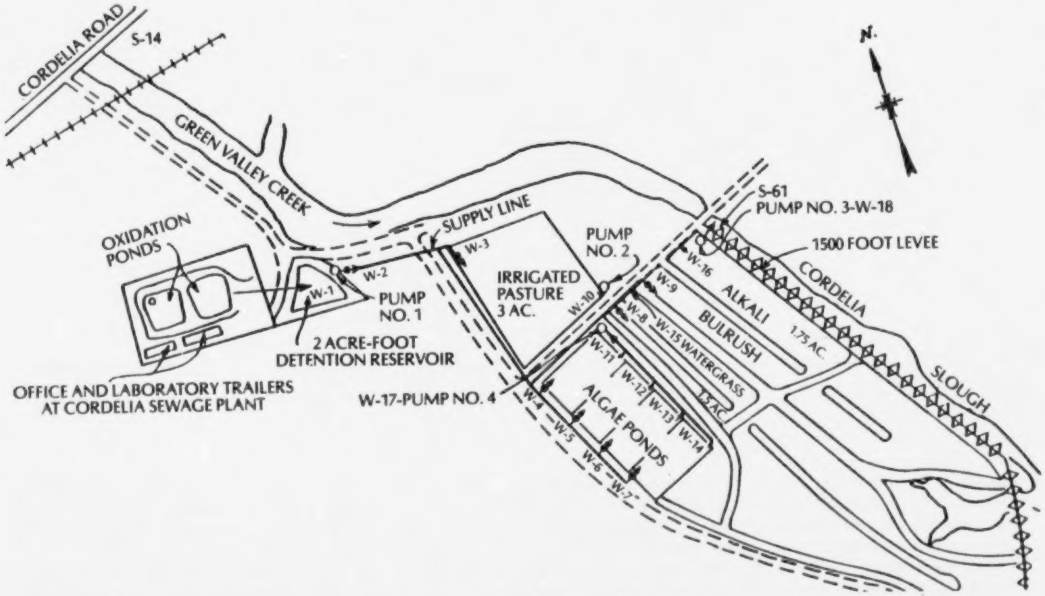


Figure 2-15. Operational units and monitoring stations at Suisun Marsh reclamation program. Major components include City of Fairfield's 0.25-mgd secondary treatment facility, a 2-acre-foot detention reservoir, a 3-acre tile-drained irrigation pasture, four marsh ponds (total area of two acres), and two 1.5-acre irrigated marsh ponds for growth of alkali bulrush and watergrass.

Most states' standards do not address the use of reclaimed water for recreational purposes. This is because nearly all recreational reuse facilities are located in California.[6] Some states, such as Utah, provide for a high degree of treatment for reclaimed water that may be used for purposes resulting in direct exposure to the public. Recreation reuse would be considered as such, on a case-by-case basis, and so would be subject to limitations on coliform densities of 3/100 ml.

Control of nutrients—phosphorus and nitrogen, primarily—is essential where excessive algae growths would interfere with the intended use of the recreational site. For landscaping ponds, managed marshlands, golf course hazard ponds, and restricted recreational use, nutrient removal generally is not necessary. At such intensive-use recreational sites as Lancaster, South Tahoe, and, formerly, Santee, California, however, control of nitrogen and phosphorus has been practiced to varying degrees to prevent algae build-up. At Lancaster, where the Sanitation Districts of Los Angeles County has provided a coagulated, filtered and disinfected oxidation-pond effluent to the county for use in its Apollo County Park recreation area, ammonia and phosphate levels are maintained at concentrations of 1.0 mg/l and 0.5 mg/l, respectively, but growth of bluegreen algae in the oxidation ponds during summer months did result in occasional turbidity problems in the recreational lakes. Santee County Water District provided an oxidized, disinfected effluent to four recreational lakes; with ammonia at 22.3 mg/l (and nitrate at 1.0 mg/l) and phosphorus at 8.0 mg/l in the oxidation-pond effluent, problems with summer algae blooms in the lakes were noted. The South Tahoe Water Reclamation Facility comprises a series of biological and physical-chemical treatment steps, including coagulation and ammonia stripping, and has reported no problems of algae growth or fish killed since the ammonia stripping process was installed.[4]

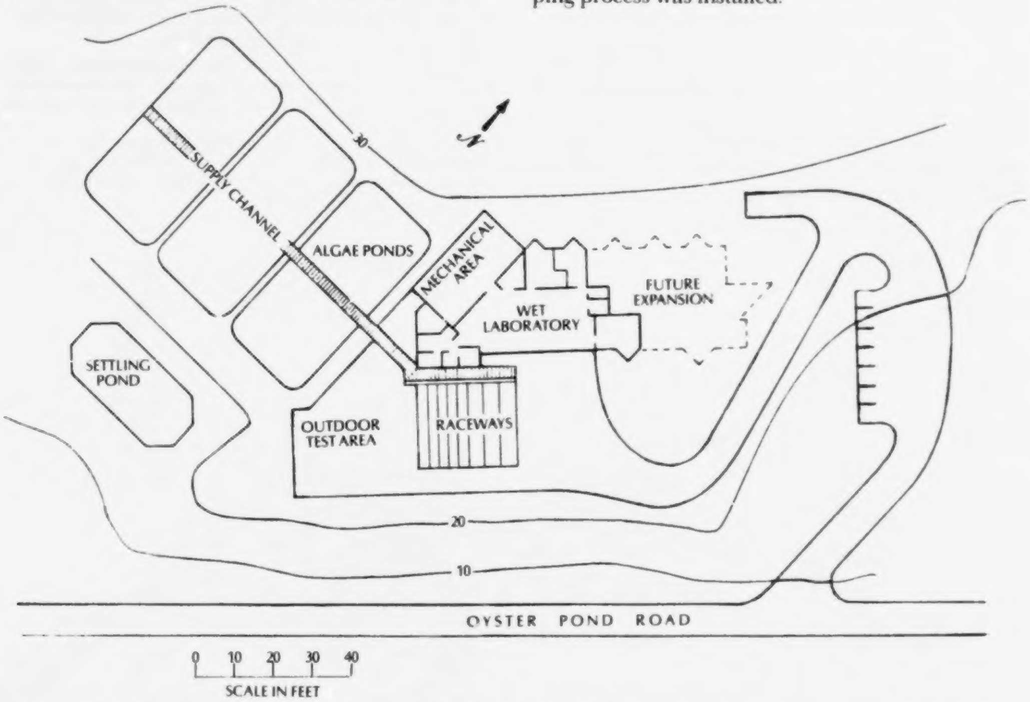


Figure 2-16. A pilot-scale aquacultural system operated since 1973 by Environmental Systems Laboratory (ESL), Woods Hole Oceanographic Institution in Massachusetts. In one series of experiments, some 8,000 gpd of secondary effluent was mixed with seawater to promote growth of marine phytoplankton cultures; harvest from the algae ponds was diverted to feeding areas—raceways—for bivalve mollusc cultures, including oysters; and effluent from the bivalve cultures supported a seaweed-growing system—again in the raceway system—that served also to "polish" effluent by removing excess nutrients. Similar experiments in marine and freshwater aquaculture have been conducted by ESL and other organizations in Florida and California, among other locations in the United States. (Source: Ryther, J.H. Preliminary Results with a Pilot-Plant Waste Recycling/Marine Aquaculture System. In: Wastewater Renovation and Reuse (F.M. D'Itri, ed.), Marcel Dekker, Inc., New York, 1977. 705 pp.)

The water-quality requirements for raising of sport fish are well-reported in the literature, but there have been very few attempts at full-scale practice using reclaimed water in the United States. The parameters of greatest concern are:

- dissolved oxygen, which should be maintained at 5 mg/l or higher;
- free ammonia, which should be reduced to below 0.02 mg/l;[15] and
- heavy metals and synthetic organic compounds (herbicides and pesticides), which can be toxic to fish and harmful as well to humans eating the fish.

Attempts so far at raising fish and other aquatic organisms in reclaimed water (Figure 2-16) indicate that the successful project will have fish culture as its main emphasis, and not as a recreational sidelight. For example, attempts at raising bass in the fourth of a series of effluent-polishing ponds at Michigan State University ultimately proved unsuccessful, because the main emphasis had been on removal of excess nitrogen in the ponds prior to year-round irrigation of selected land sites. Nitrogen stripping in the ponds led to dominance of nitrogen fixing bluegreen algae, causing near-total oxygen depletion and resultant fish kills.[27]

GROUNDWATER RECHARGE

Reclaimed water has been used to recharge aquifers in several areas of the United States where excessive groundwater withdrawals have caused serious water-supply problems. By recharging the depleted aquifers, water agencies can prevent ground subsidence and, in coastal areas, salt-water intrusion into the freshwater supply. If the aquifer is also to be used as a source of nonpotable water, recharge restores a nonpotable supply to shallower wells that had been pumped dry, thereby reducing pumping costs. Moreover, the infiltration process can provide additional treatment to the reclaimed water. Facilities for full-scale groundwater recharge with reclaimed water are currently in operation or under construction at about 10 locations in the United States.[4]

No consistent water-quality standards or recommended treatment method has been advanced at the state level for use of reclaimed water for groundwater recharge; these would, of course, vary widely, according to intended use (if any) after recharge, method of recharge, and local soil and hydrogeological characteristics. Florida, for example, permits discharge to shallow potable aquifers only if "no other alternative is available and the proposed facility will be temporary."

Two methods of recharge are commonly used. Reclaimed water can be applied to spreading basins overlying the aquifer and allowed to percolate through the soil to recharge the supply. Depending on the soil leaching characteristics, pH, and other properties, some additional treatment is given to the reclaimed water by this percolation process. Or reclaimed water can be pumped directly into the aquifer via injection wells (Figure 2-17). Reclaimed water for direct injection must be of high quality, in order to avoid clogging the well and the aquifer in the vicinity of the well.

Recharge of groundwater aquifers with reclaimed water offers distinct advantages, in that it can help to solve local problems of subsidence or saltwater intrusion (Figure 2-18) while also providing storage for nonpotable reuse—typically in irrigation, recreational and industrial applications.

One problem with recharge is that boundaries between potable and nonpotable aquifers are rarely well-defined. There is usually incurred some risk of contaminating high-quality potable-water groundwater supplies by recharging "nonpotable" aquifers with reclaimed water. The recognized lack of knowledge about the fate and long-term health effects of contaminants found in reclaimed water, such as heavy metals and synthetic organic chemicals, forces a conservative approach to setting of water-quality standards in groundwater recharge. There is currently no evidence of biodegradation of chlorinated organics in aquifers, for example, although adsorption in the aquifer strata can delay transport of these contaminants for a considerable period. Research has been underway since 1976 to answer the following questions related to aquifer recharge with reclaimed water:[28]

- How effectively are pollutants removed during travel through an aquifer, both in the long term and in the short term?
- What are the mechanisms of removal or transformation?
- What are the end products of transformation?
- How rapidly are pollutants transported through an aquifer compared to the water with which they are introduced?

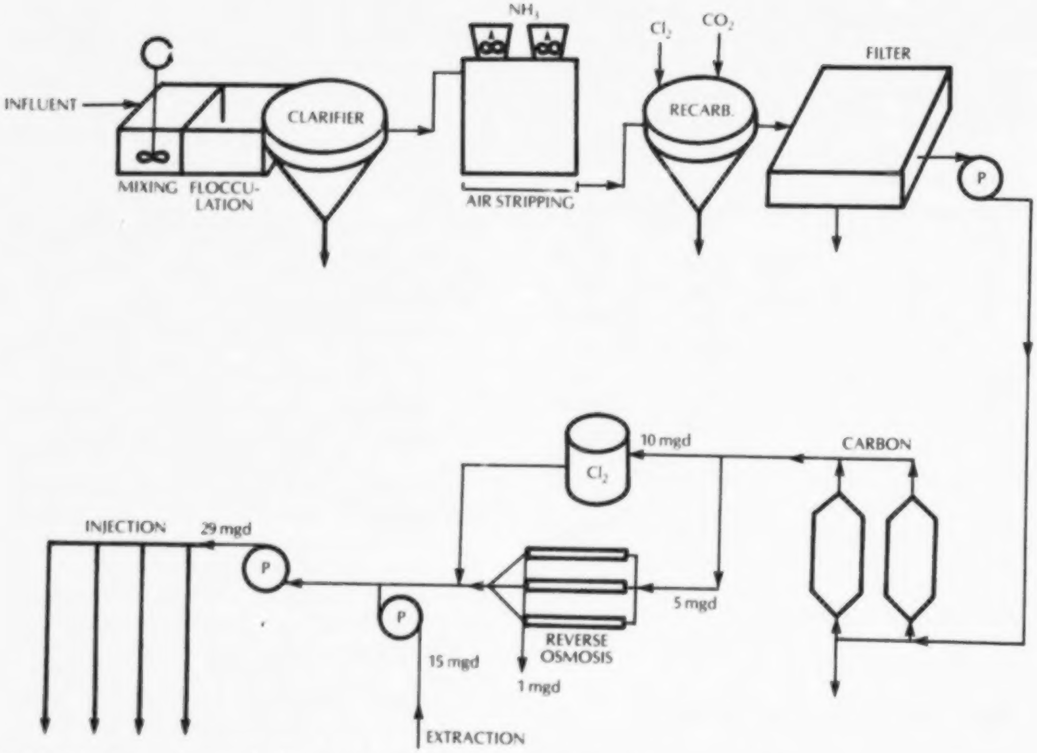
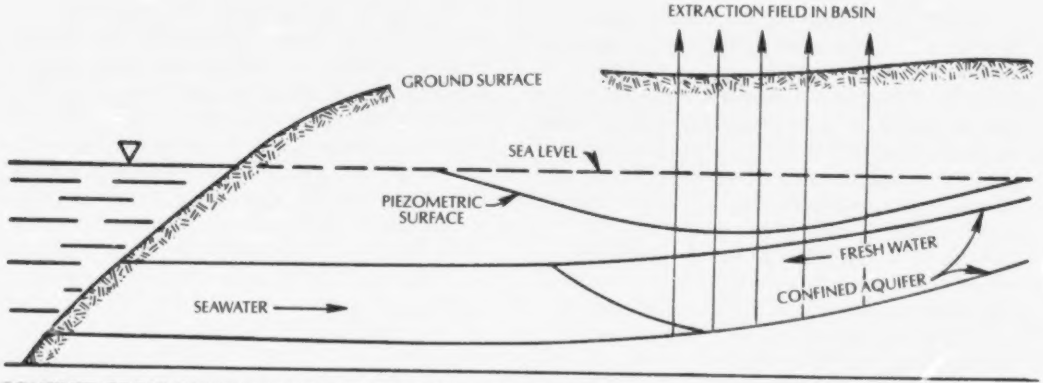
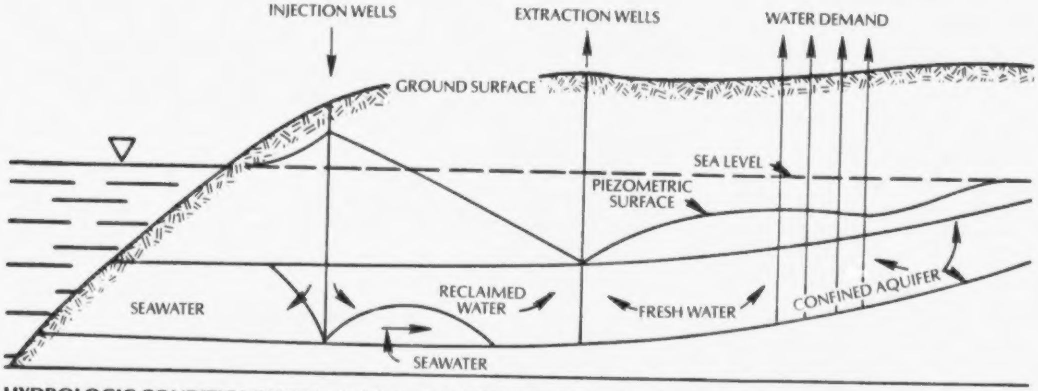


Figure 2-17. Process schematic for 15-mgd Water Factory 21 operated by the Orange County (California) Water District. Reclaimed water from Water Factory 21 is blended with a like amount of deep well water and injected into groundwater basins to control saltwater intrusion, which by 1976 had progressed up to four miles inland from the Pacific Ocean. (Source: Highlights of California's Water Factory 21. Municipal Wastewater Reuse News, Vol. 1, AWWA Research Foundation, Denver, Colorado, October 1977. pp. 15-23.)



CONFINED GROUNDWATER BASIN SUBJECT TO SEAWATER INTRUSION



HYDROLOGIC CONDITIONS WITH AN INJECTION/EXTRACTION WELL SYSTEM
(WITH THE EXTRACTION WELLS INLAND OF THE INJECTION WELLS)

Figure 2-18. Recharge of a groundwater aquifer with reclaimed water can control saltwater intrusion in coastal zones. Note suggested use of injection/extraction pairs to help prevent movement of recharged water into potable aquifers. (Source: Wedding, J.J. *et al.* Use of Reclaimed Wastewater to Operate a Seawater Intrusion Control Barrier. Proceedings of the Water Reuse Symposium, Vol. 1, AWWA Research Foundation, Denver, Colorado, 1979. pp. 639-662.)

The State of California, too, has reacted to the uncertainties surrounding recharge of groundwater with reclaimed water. Following a three-agency review in 1975 of health aspects associated with this type of reuse,[29] the California Department of Health Services amended Title 22 in 1978 to impose requirements for stringent case-by-case review of any proposed new reclaimed-water recharge scheme that could involve "a potential risk to public health" (Article 5.1 of Title 22). The Department must review and evaluate relevant aspects that include "treatment process, effluent quality and quantity, spreading area operations, soil characteristics, hydrogeology, residence time, and distance to withdrawal," then hold a public hearing and submit its recommendations to the Regional Water Quality Control Board. In practice, recharge is approved only when it can be demonstrated that there is no risk of contaminating higher-quality aquifers.

In light of these uncertainties, states have recommended that treatment standards for recharge be linked both to the intended use of water pumped from the recharged aquifer, and to the possibility of contaminating nearby aquifers of higher quality. Therefore, treatment standards for recharge would be as high (or higher) for any ultimate reuse as they would be for direct use of the reclaimed water for the same purpose. Were water to be pumped from the recharged aquifer and used for recirculating industrial cooling, the recommended treatment might follow the suggested treatment processes in the next section. And, if there were risk of contaminating higher-quality aquifers, it would probably be necessary to add still higher levels of treatment, including carbon adsorption and/or demineralization (Figure 2-19). Because groundwater resources are valuable and finite, and their cleansing after contamination might take many years, recharge of groundwater with reclaimed water is being approached conservatively, on a case-by-case basis, by all states.

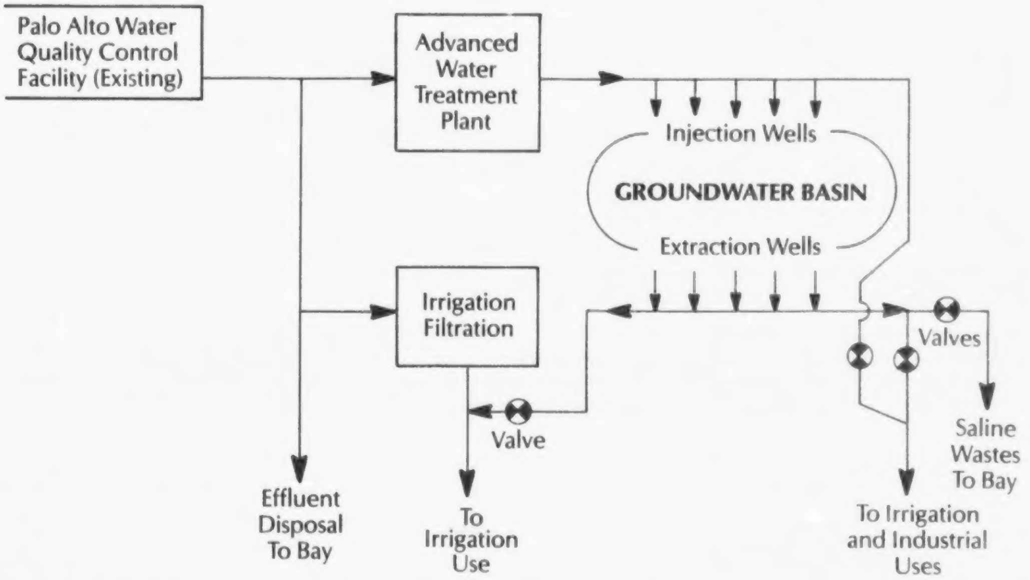


Figure 2-19. In Palo Alto, California, a 2-mgd water-reclamation operation provides secondary effluent with lime treatment, air stripping, recarbonation, ozonation, filtration, GAC adsorption and chlorination, prior to injection of the reclaimed water into a relatively homogeneous aquifer. Monitoring of the groundwater basin since 1976 has provided researchers with information on migration of organic constituents in reclaimed water through a recharged aquifer. The figure above illustrates the ultimate reuse plan conceived for the Palo Alto facilities, which were constructed by the Santa Clara Valley Water District and are operated by the City of Palo Alto. (Source: AWWA Research Foundation. Continued Highlights of Pomona Groundwater Recharge Conference. Municipal Wastewater Reuse News, No. 27, December 1979. pp. 10-14.)

INDUSTRIAL AND LARGE-SCALE COMMERCIAL REUSE

Reuse of reclaimed water for industrial and large-scale commercial applications represents one of the most underexploited market areas in the U.S. Industries often use more water than other consumers, often can tolerate water that is of less than drinking-water quality, and often are centrally located near populated areas that generate wastewater. Industrial uses for reclaimed water include cooling, boiler feed, washing, transport of material, processing, and use as a product ingredient (food-processing uses are not considered in these guidelines). Of these, cooling is the predominant reuse application, accounting for about 99 percent of the total reported volume of industrial reuse (see Table 2-8).

Cooling Water. Cooling water systems can be broadly classified as "once-through" or "recirculating."

Once-through cooling uses intake water for only one cooling cycle before discharge. The intake water need not always be of high quality. Seawater and polluted river waters are commonly used with minimal treatment, such as coarse screening and periodic shock chlorination for slime control. Among the water-quality factors of concern in use of reclaimed water for once-through cooling are (1) the potential for accumulation of deposits from suspended matter in the water, and (2) the possibility of biological activity producing slime growths in the cooling system. The temperature of the reclaimed water can also be important in once-through systems; higher temperatures of reclaimed water in

Table 2-8. INVENTORY OF FACILITIES USING RECLAIMED WATER FOR COOLING*

Location	User Entity	Date Started	Water Use[a] (mgd)	Additional Treatment Following Municipal Wastewater Treatment[b]
Amarillo, Texas	Southwestern Public Service Co.	1961	10.0	Lime clarification, pH adjustment, shock chlorination, corrosion inhibitor.
Baltimore, Maryland	Bethlehem Steel Co.	1942	106.0	Chlorination.
Burbank, California	City Power Generating Station	1967	2.0	Shock chlorination, pH adjustment, corrosion inhibitor, antifoam agent.
Clark County, Nevada	Nevada Power Co.	NA	12.5	Lime clarification, chlorination.
Colorado Springs, Colorado	City Electric, Martin Drake Plant	1960	21.0	Lime clarification, filtration, GAC adsorption, chlorination.
Contra Costa County, California	Contra Costa County Water District	1979	15.0	Sodium ion exchange softening.
Denton, Texas	Municipal Steam Electric Plant	1972	1.3	Shock chlorination, pH adjustment, corrosion inhibitor.
Enid, Oklahoma	Champlin Refinery	NA	2.0	NA
Glendale, California	City of Glendale	1978	5.7	Chemical addition, flocculation, sedimentation and filtration.
Las Vegas, Nevada	Nevada Power Co.	1964	27.0	Shock chlorination, lime clarification, pH adjustment, corrosion inhibitor.
Los Alamos, Texas	Zia Corporation	1951	0.3	Shock chlorination, pH adjustment, corrosion inhibitors. Algae growth controlled by intermittent drying of towers.
Lubbock, Texas	Southwestern Public Service Co.	1970	6.5	Lime clarification, pH adjustment, shock chlorination, corrosion inhibitor. Boiler feed required filtration, reverse osmosis and ion exchange.
Midland, Michigan	Dow Chemical Co.	NA	6.0	NA
Odessa, Texas	El Paso Products Co.	1950s	4.8	Lime clarification, recarbonation, pH adjustment, filtration, ion exchange softening, antifoam agent.

1 mgd = 3,785 cubic meters per day

*from[5] and other sources

[a] Mainly for cooling, but in some cases also for boiler feed and dilution of blowdown.

[b] Municipal wastewater treatment by activated-sludge process, except for Colorado Springs, Los Alamos and Las Vegas (trickling filters) and Glendale and Contra Costa County (activated sludge plus filtration).

summer might require installation of greater cooling capacity in the system. Treatment requirements for once-through cooling will vary on a case-by-case basis. In general, secondary effluent can be used without addition of chemicals, although in some instances the effluent should be filtered in order to control suspended solids.

Recirculating evaporative cooling systems, on the other hand, continually recirculate the same cooling water for many cycles by utilizing cooling towers or spray ponds to re-cool the water after each heat-exchange cycle. To prevent an unacceptable build-up of contaminants due to evaporation, a portion of the recirculating water is continuously wasted, in "blowdown." To replace the volume lost in blowdown, the recirculating cooling system requires make-up water. Because any contaminants present in make-up water are concentrated many times during the cooling cycle, and because organic nutrients in the make-up water furnish food for organisms, make-up water must be of high quality.

Reclaimed water treated to a high degree is successfully used for cooling make-up water at a number of locations in the United States. Cooling water:

- must not form scale on heat-exchange surfaces;
- must not be corrosive to metal in the cooling system (corrosion inhibitors can be used, as indicated in Table 2-8);
- must not supply nutrients promoting the growth of slime-forming organisms;
- must not foam excessively; and
- must not cause the wood in cooling towers to deteriorate.

The literature provides a number of tables listing water-quality criteria for cooling-water supplies, as summarized in Table 2-9. Treatment requirements vary, depending on the materials of construction and the type of treatment given to the reclaimed water. In general, the treatment steps most commonly found to be appropriate consist of lime treatment, which

Table 2-9. RECOMMENDED COOLING-WATER QUALITY CRITERIA FOR MAKE-UP WATER TO RECIRCULATING SYSTEMS*

Parameter	Recommended Limit[15]	Recommended Limit[30]	Comments[30]
Cl	500	100-500	
TDS	500	500-1,650	
Hardness ($CaCO_3$)	650	50-130	
Alkalinity ($CaCO_3$)	350	20	
pH	**	6.9-9.0	Preferably 6.8-7.2
COD	75	75	Preferably below 10
TSS	100	25-100	Preferably below 10
Turbidity	—	50	Preferably below 10
BOD	—	25	Preferably below 5
Organics (methylene blue active substances)	1	2	2 is good
NH_4	**	4	Preferably below 1
PO_4	—	1	1 is good
SiO_2	50	—	
Al	0.1	0.1	
Fe	0.5	0.5	
Mn	0.5	0.5	
Ca	50	50	
Mg	**	0.5/**	
HCO_3	24	24	
SO_4	200	200	

*from[15,30]. Required limits in mg/l, except for pH units.
**Accepted as received.

softens the water and removes phosphorus, a number of the metals, and removes ions and organic compounds; filtration, if necessary; and disinfection, both to control slime growth and to remove bacteria and viruses that are dispersed in the cooling-tower aerosol plume. At Burbank, California, where secondary effluent is used, it has not been found necessary to provide a phosphorus-removal step (Figure 2-20). In Las Vegas, Nevada, however, the Nevada Power Company uses an unfiltered secondary effluent and itself provides lime clarification for reduction of turbidity and phosphorus (D. Okun, personal communication). Additional treatment steps, as necessary, can be provided at either the WWTP or the user site. One advanced-treatment facility designed to produce reclaimed water for cooling-tower make-up is now in operation in Glendale, California. Some 5.7 mgd of filtered secondary effluent is pumped approximately 7,000 feet from the existing Los Angeles/Glendale Water Reclamation Plant to the Glendale Steam Electric Generating Plant. Additional treatment of the effluent consists of alum or sodium aluminate addition, clarification in solids-contact units, and dual-media filtration prior to reuse.[31]

Boiler-Feed Water. The use of reclaimed water for boiler-feed water is usually not economical, due to the requirements for extensive additional treatment. Quality requirements for boiler-feed make-up water are dependent upon the pressure at which the boiler is operated. The higher the pressure, the higher the quality of water required. Very high-pressure boilers require make-up water of distilled quality. Table 2-10 shows quality tolerances recommended in the EPA's "Blue Book."[15]

In general, the users of reclaimed water for boiler-water make-up reduce the hardness of the boiler-feed make-up water to close to zero. Depending on the characteristics of the wastewater being treated and the requirements for the reclaimed water, lime treatment (including flocculation, sedimentation and recarbonation) might be followed by multimedia filtration, carbon adsorption and nitrogen removal. High-purity boiler-feed water for high-pressure boilers might also require treatment by reverse osmosis or ion exchange (Figure 2-21). The presence of silica and aluminum in the reclaimed water is very undesirable, because these form a hard scale on heat-exchanger surfaces. Potassium and sodium in high concentrations can cause excessive foaming in the boiler water.

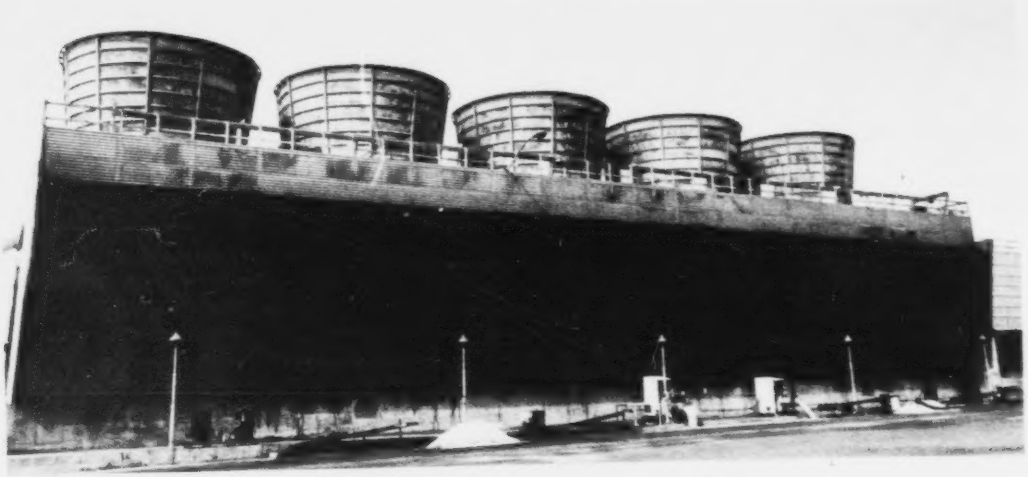


Figure 2-20. Cooling towers at Burbank, California, where the Public Works Department uses some 2 mgd of disinfected high-quality secondary effluent as cooling water.

Process Water. Process water is related to the particular use for water within the various industries. For example, the electronics industry requires water of almost distilled-water quality for washing circuit boards and other electronic components. On the other hand, the tanning industry can use large quantities of relatively low-quality water.

Requirements for textiles, pulp and paper, metal fabricating, etc. are intermediate. Thus, it will be necessary to contact all potential users to determine their specific requirements for process water. Of course, industrial users who have relied for years on high-quality water provided through a municipal supplier might not know themselves whether reclaimed water can serve their purposes. It might well be necessary, in such cases, to contact and visit similar industrial installations that are already using lower grades of water, or to conduct pilot tests prior to project implementation that will demonstrate what limitations, if any, will be imposed by use of reclaimed water.

Where an extremely high degree of treatment is needed, it might be more economical for the provider of reclaimed water to furnish a filtered supply that can meet most needs in the community, and have the using industry upgrade the product water to meet its particular requirements.

Table 2-10. RECOMMENDED INDUSTRIAL BOILER-FEED WATER QUALITY CRITERIA*

Parameter	Low Pressure (psig)	Intermediate Pressure (psig)	High Pressure (psig)
Silica (SiO_2)	30	10	0.7
Aluminum (Al)	5	0.1	0.01
Iron (Fe)	1	0.3	0.05
Manganese (Mn)	0.3	0.1	0.01
Calcium (Ca)	**	0.4	0.01
Magnesium (Mg)	**	0.25	0.01
Ammonia (NH_4)	0.1	0.1	0.1
Bicarbonate (HCO_3)	170	120	48
Sulfate (SO_4)	**	**	**
Chloride (Cl)	**	**	**
Dissolved Solids (TDS)	700	500	200
Copper (Cu)	0.5	0.05	0.05
Zinc (Zn)	**	0.01	0.01
Hardness ($CaCO_3$)	350	1.0	0.07
Alkalinity ($CaCO_3$)	350	100	40
pH, units	7.0-10.0	8.2-10.0	8.2-9.0
Organics:			
Methylene blue active substances	1	1	0.5
Carbon tetrachloride extract	1	1	0.5
Chemical oxygen demand (COD)	5	5	1.0
Hydrogen sulfide (H_2S)	**	**	**
Dissolved oxygen (O_2)	2.5	0.007	0.007
Temperature F	**	**	**
Suspended Solids	10	5	0.5

*from[15]. Recommended limits in mg/l except for pH (units) and temperature (degrees Fahrenheit).

**Accepted as received (if meeting other limiting values); has never been a problem at concentrations encountered.

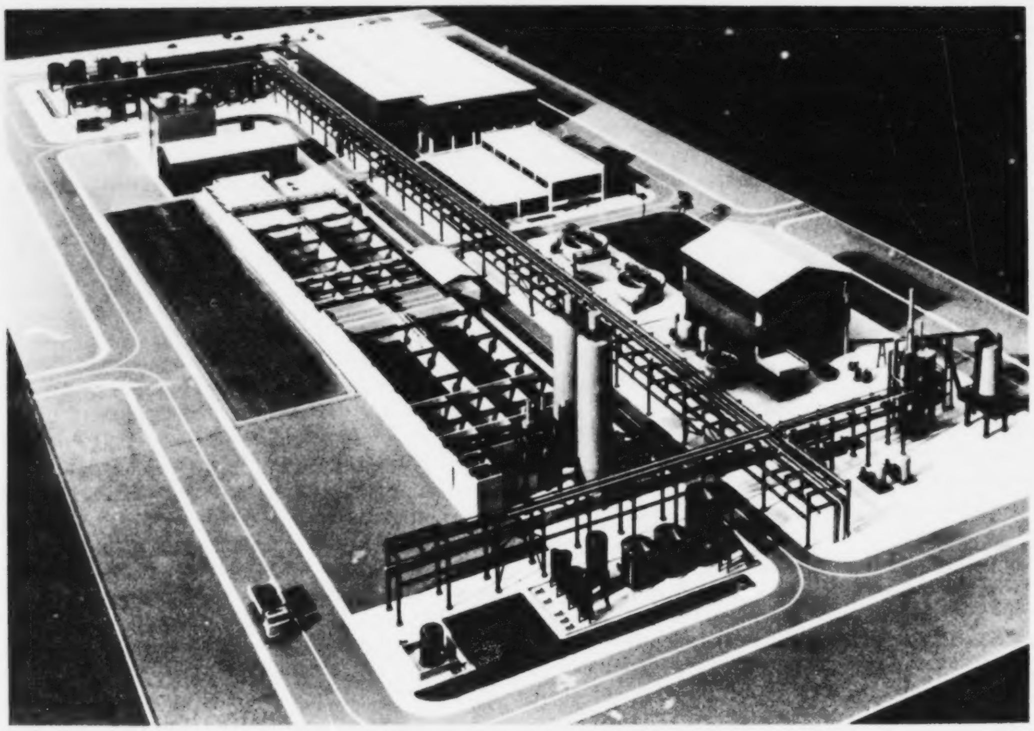


Figure 2-21. In Riyadh, Saudi Arabia, increased water requirements for expansion of the Petromin oil refinery has spurred development of a high-quality industrial reuse plan that is now nearing start-up. Up to 5.3 mgd of secondary-treated wastewater effluent will receive varying degrees of treatment at the facilities (pictured as a model above) for use as utility water (hose station and fire water), intermediate quality water for cooling tower make-up and desalting, and boiler-feed water. The full treatment train for boiler-feed water encompasses two-stage lime treatment, dual-media filtration, granular activated carbon adsorption, two-stage reverse osmosis and ion-exchange demineralization processes. (Source: Camp Dresser & McKee Inc.)

Environmental Impacts

A variety of environmental issues have impacts on water-reuse applications. Reuse planning should be conducted with these issues in mind, both in anticipation of possible requirements for environmental impact assessment, and in order to respond to any general public concern over the use of reclaimed water. An environmental assessment will be necessary in some states, and wherever federal funds are used. Even if your project is funded wholly from local sources, you should check to see if your state requires an impact statement in support of any significant expenditure of municipal funds.

Following is a discussion of some representative issues which could be important in impact assessment for a reuse project.

LAND USE

Water reuse can induce land-use impacts that could be considered either beneficial or detrimental. If a community's growth had been limited by the capacity of the water supply, and if, through water reuse, the portion of the potable supply available to residents were increased, then development that had previously been excluded could occur. In most cases, the decision-making process involved in implementing reclamation and reuse forces examination of community goals. In Westminster, Colorado, for example, a water-exchange program between the city and area farmers is tied directly into a comprehensive six-point growth and resource-management plan that includes establishment of land-use priorities, fiscal impact planning, and conservation programs.[32]

CASE STUDY:
An Example of Environmental Issues in Reuse

In some cases, instituting a reuse program means that communities can reduce their discharge of polluting substances to vulnerable waterways. The potential effects of reuse must be studied, however, to ensure that the desired end will be achieved. Recent studies by engineers in British Columbia, Canada have indicated that in at least one case, high-volume reuse of effluent for agricultural irrigation could hasten, not retard, the rate of lake eutrophication caused by nutrients' loading.

The Okanagan Valley is located 200 miles inland of the Pacific Ocean, north of Washington state. It is about 100 miles long and averages 30 miles in width; the basin drains into Washington and is tributary to the Columbia River. It is an arid region, parts of it receiving less than ten inches of precipitation each year.

Several agencies in the Valley have long considered agricultural reuse of reclaimed water to be both necessary and desirable. Projected water use in 2020 can be projected to approach lake-system throughflow, due to rapidly-increasing residential/industrial and agricultural development. Reuse would avoid costly AWT to meet pollution-control requirements and to eliminate point-source input of phosphorus, which is believed to have created eutrophic conditions in the lakes. And agricultural reuse would assure farmers of ample water for irrigating 60,000 acres of existing orchard land and up to 400,000 acres of additional new farmland now under development.

According to a study made by Dayton & Knight Ltd. engineers, however, reuse would not achieve all of the desired goals over the long term. Complete reuse of treated-wastewater effluent could, in fact, nearly triple lake flow-through time within 40 years and so reduce the flushing of phosphorus that now occurs. In addition, assuming that nonpoint loadings of phosphorus are related to agricultural acreage, the nonpoint source contribution of phosphorus could increase from 300,000 pounds per year at present to 800,000 pounds per year in 40 years.

In summary, the engineers point out that "the effects on pollution and eutrophication from the prolonged lake water flow-through rate and from potential additional nonpoint source contribution of phosphorus should receive considerably more attention...because both are the classic causes of the premature aging of lakes, in addition to point-source contributions of phosphorus from growing shoreline populations."

Source: Dayton, M.J.J. and A. Berzins. Accelerated Surface Water Eutrophication from Land Disposal of Sewage. In: Proceedings of the Water Reuse Symposium, Vol. 3. AWWA Research Foundation, Denver, Colorado, 1979. pp. 2104-2119.

Water reuse can encourage a more efficient or more intensive use of land in the municipality. If parks or golf courses can be developed where previously there have only been fields, or if more intensive use can be made of agricultural land by virtue of having more irrigation water available, then the land can be used more efficiently. A water-reuse program might result in a more dramatic change in land-use—for example, if a small manufacturing facility (attracted by the water source) were sited on a previously-undeveloped site, or if the availability of reclaimed water prompted new residential development with more effective use of open space.

ECONOMIC

Reuse planning has enabled some communities to develop municipal recreational facilities. For others, it could help to keep local industry in the community. Reuse to promote conservation or to fill a recreational need will provide a social good to the whole community. Reuse that provides local industry with a more economical or secure source of water might assure that an important source of employment remains in the community.

In periods of drought, reclaimed water provides a reliable source of water for landscape irrigation or industrial processing, thereby protecting the investment made in landscape plants or in materials. For farmers, the nutrient value of reclaimed water can mean savings in fertilizer costs of up to $30 per acre-foot of reclaimed water used. In Amarillo, Texas, three distinct advantages of water reuse have been identified: the revenues generated have helped to offset the costs of constructing new water-treatment facilities; the supply of low-cost industrial water has helped to bring industry to the community; and the city's potable-water supply is being protected for more valuable use.[4]

A reuse program can result in lowering local sewer charges, particularly if sale of the reclaimed water increases the wastewater-treatment service revenues, or results in treatment economies-of-scale or reduced pretreatment requirements. Water reuse might make more water available during times of water shortage, as a result of the decreased demand on the community's potable water supply.

The relocation of wastewater-effluent discharges can have adverse impacts on streamflow or groundwater levels. (A variation of this type of problem occurs when new wastewater-treatment plants, discharging treated effluent through an ocean outfall, replace smaller on-site facilities that discharge treated effluent to streams and/or to the ground.) With irrigation or evaporative cooling applications of reclaimed water, a point-source discharge into a stream is reduced or eliminated, and, consequently, streamflow is substantially decreased. Such a decrease could alter the ecosystem supported by that stream and could also decrease the supply of water available to users downstream.

Quality Assurance

The success of any reuse plan depends on the reliability of its components and the assurance of safe reclaimed water. Treatment processes for reclaiming water must be reliable in delivering the quality of water required. Provision of equalizing storage can serve effectively toward assuring water quality. Most reuse applications require the features described below, although somewhat more fluctuation in water quality can be tolerated for some types of irrigation use. The second consideration is user safety. In both treatment and conveyance, the fundamental goal must be to provide reclaimed water that poses no hazard to the user, the user's employees, or the general public.

RELIABILITY IN TREATMENT

Alarms provide warnings of power failure or failure of any important unit process. Alarm devices are a necessity at all treatment facilities, especially at facilities where no employees are stationed full-time (in which case the alarm should be connected to a full-time service unit, such as a police or fire station). Continuous automatic monitoring devices are available for measuring temperature, dissolved oxygen, pH, conductivity, turbidity and other parameters. Some reclamation facilities, requiring a high-level of monitoring, use bacteria, *Daphnia*, and fish species for biotoxicity monitoring.[33]

Water-reclamation facilities should be equipped with an automatic standby power source, and emergency storage or disposal facilities. You can provide for emergency storage with retention ponds that can serve for flow-equalization as well, thereby permitting the overflow to return to the influent. Storage can also be provided in groundwater aquifers suitable for recharge. At a 20-mgd water reclamation facility in St. Petersburg, Florida, reclaimed water is distributed for irrigation use through a separate 14-mile system. During periods of low demand—when it rains, for example—the reclaimed water will be pumped to 900 feet underground, displacing brackish water there and creating an underground reservoir for future water withdrawal. Of course, if the secondary WWTP from which effluent is obtained discharges to a waterway, water can simply be discharged through the existing outfall if the reclamation facilities are inoperative or if reclaimed water fails to meet reuse standards.

Other features for reliability are modeled after facilities commonly used in treatment systems for potable water supply. For example, chlorination facilities should be provided with the following features: standby chlorine supply and facilities, including such things as manifold systems to connect chlorine cylinders, chlorine scales, automatic devices for switching over to full chlorine cylinders, automatic dosage control and residual recording.[34] Other methods of disinfection should have equivalent reliability.

Of equal importance to the reliability of reclamation facilities is a well-trained and experienced staff. The facility's operation should be based on detailed process-control with recording and monitoring facilities, a strict preventive-maintenance schedule, and standard-operating-procedure contingency plans to assure the reliability of the product water quality. By the same token, the reclaimed-water user must employ safe practices in the handling, distribution and use of water, to avoid exposing the public to any health risk. These aspects will be particularly important during the first few years of operation, when the reuse system must "prove itself."

The State of California Department of Health Services has published detailed guidelines for reliability in wastewater-reclamation facilities; the guidelines include discussion of emergency procedures, power supply, frequency of bacteriological analysis, and requirements for disinfection.[34] In addition, Articles 8, 9, and 10 of the State's Title 22 regulations provide an excellent outline of design and operational considerations covering alarms, power supply, redundancy features, emergency storage and disposal, and chemical supply, storage and feed facilities.

SAFETY IN CONVEYANCE AND DISTRIBUTION

The State of California Department of Health Services has established operational standards designed to assure the reliability and safety of reclaimed water programs. They are shown below:

- The discharge should be confined to the area designated and approved for disposal and reuse.
- Maximum attainable separation of reclaimed water lines and domestic water lines should be practiced. Domestic and reclaimed water transmission and distribution mains should conform to the "Separation and Construction Criteria" (see Table 2-11).
- All reclaimed water valves and outlets should be appropriately tagged to warn the public and employees that the water is not safe for drinking or direct contact.

California does not yet require monitoring on the nonpotable distribution system, but this has been recommended.[19] When the reclamation and reuse program in a community involves a dual water-supply system, special measures should be taken. Piping, fittings, and plumbing should be well marked, distinguished from the potable supply by color, material and jointing. A strict plumbing code should be developed with agency supervision of pipeline construction and plumbing installations. Such guidelines have been developed for several reuse programs, including those for the Irvine Range Water District (IRWD), California (Figure 2-22) and the City of St. Petersburg, Florida.[7,14]

The Irvine Ranch Example. At Irvine Ranch, steps taken to ensure safety in conveyance of reclaimed water include the following:

Training: The Water District staff has prepared a comprehensive manual on reclaimed-water use and has instituted an on-going education program to promote understanding of cross-connection control.

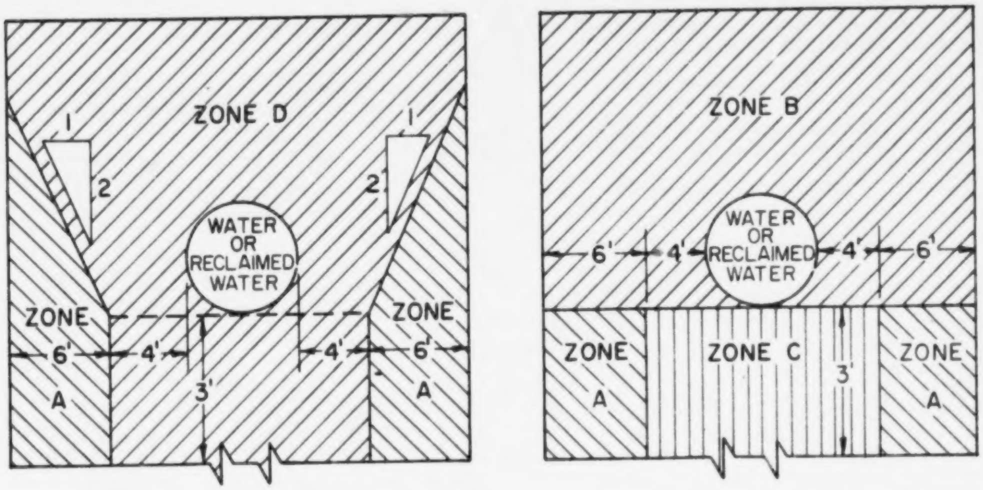
Supervision: Each entity receiving reclaimed water has a trained staff person directly responsible for separation of the reclaimed water system. New construction must be approved and field-inspected by the district before reclaimed water can be used.

Piping: Pipes for distribution of reclaimed water must have the words RECLAIMED WATER stenciled on both sides, at intervals of approximately six feet. Warning tapes may also be placed directly atop the pipe. PVC piping carrying reclaimed water for irrigation is either white with green stenciling or green with white stenciling. PVC piping carrying potable water is blue in color.

Valves: All valves are located below grade in a valve box with locking green cover.

Intersections: All intersections of the reclaimed-water and potable-water systems are designed to meet the same requirements as for water-sewer intersections. For example, the standards require use of special pipe materials at intersections, and use of minimum horizontal and vertical clearances.

The State of California Department of Health Services has established the IRWD plan as the prototype for nonpotable urban distribution systems throughout the state. Among the requirements for these systems are: non-standard threading, color coding of pipes, special connectors between the street connection and the sprinkler grid, no hose bibbs on the nonpotable system, backflow prevention devices, and other safeguards.



PARALLEL CONSTRUCTION

PERPENDICULAR CONSTRUCTION

IF ANY OF THE THREE PIPELINES, WATER, RECLAIMED WATER, OR SEWER, ARE WITHIN ANY OF THE ABOVE INDICATED ZONES, SPECIAL CONSTRUCTION WILL BE REQUIRED AS SHOWN BELOW.

IF ANY OF THE THREE PIPELINES; WATER, RECLAIMED WATER, OR SEWER; ARE TO BE LOCATED WITHIN ANY OF THE ABOVE INDICATED ZONES, SPECIAL CONSTRUCTION WILL BE REQUIRED AS SHOWN BELOW.

IF ANY OF THE THREE PIPELINES; WATER, RECLAIMED WATER, OR SEWER CROSS WITHIN ANY OF THE ABOVE INDICATED ZONES, SPECIAL CONSTRUCTION WILL BE REQUIRED AS SHOWN BELOW.

CONSTRUCTION REQUIREMENTS

ZONE	SEWER	RECLAIMED WATER
A	V.C.P. WITH COMPRESSION JOINTS.	A.C.P. OR P.V.C. AS SPECIFIED IN PART III.
B	C.I.P. WITH LEAD OR APPROVED MECH. JOINTS OR V.C.P. IN STEEL CASING.	C.I.P. WITH LEAD OR APPROVED MECH. JOINTS; OR A.C.P., OR P.V.C. IN STEEL CASING.
C	V.C.P. ENCASED IN CONCRETE OR ANY OF ZONE B CONSTRUCTION METHODS.	A.C.P. OR P.V.C. ENCASED CONCRETE OR ANY OF ZONE B CONSTRUCTION METHODS.
D	DO NOT LOCATE ANY PARALLEL SEWER IN THIS AREA WITHOUT HEALTH DEPARTMENTS APPROVAL.	DO NOT LOCATE ANY PARALLEL RECLAIMED WATER MAIN IN THIS AREA WITHOUT HEALTH DEPARTMENT APPROVAL.

ASBESTOS CEMENT PIPE WITH RUBBER RING JOINTS APPROVED FOR FORCE MAINS MAY BE PLACED IN ZONE A.

MECHANICAL COMPRESSION JOINTS CONFORMING TO A.S.T.M. C425 "VITRIFIED CLAY PIPE JOINT USING MATERIAL HAVING RESILIENT PROPERTIES." EXAMPLES ARE "WEDGELOCK" AND "SPEEDSEAL" JOINTS.

Figure 2-22. Example of construction specifications for dual distribution system.
(Source: Irvine Ranch Water District. Standard Specifications for the Construction of Water, Sewer, and Reclaimed Water Facilities. Orange County, California, March 5, 1979.)

Table 2-11. SEPARATION AND CONSTRUCTION CRITERIA*
DOMESTIC AND RECLAIMED WASTEWATER TRANSMISSION AND DISTRIBUTION MAINS
CALIFORNIA DEPARTMENT OF HEALTH

BASIC SEPARATION		WATER MAIN INVOLVED		RECLAIMED WASTEWATER MAIN CONSTRUCTION MINIMUM SEPARATION IF BASIC SEPARATION IS NOT FEASIBLE		
Parallel Construction	**Perpendicular Construction** (Potable above reclaimed)	**Reclaimed Wastewater**	**Domestic Water**	**Parallel Construction**	**Perpendicular Construction** (Reclaimed wastewater and **above** domestic water main)	**Perpendicular Construction** (Reclaimed wastewater main **below** domestic water main, clearance less than three (3) feet)
25 ft	3 ft	Pressure	Gravity (less than 5 psi)	No exception	Minimum pipe class 2 x wwp; steel casing 25 ft both sides of crossing	Minimum pipe class 2 x wwp; steel casing 25 ft both sides of crossing
25 ft	3 ft	Gravity	Gravity	VCP, AC, CIP, or equal class 150; 15 ft minimum separation; mechanical compression joints	Steel casing 25 ft both sides of crossing	VCP, AC, CIP, or equal, class 150; mechanical compression joints 25 ft both sides of crossing
10 ft	3 ft	Pressure	Pressure	Minimum pipe class 2 x wwp; 4 ft minimum separation; no common trench	Minimum pipe class 2 x wwp; mechanical compression joints 4 ft both sides of crossing	Minimum class 2 x wwp; mechanical compression joints 4 ft both sides of crossing
10 ft	3 ft	Gravity	Pressure	VCP; 4 ft minimum separation; mechanical compression joints	Concrete encasement or steel casing 4 ft both sides of crossing	VCP, AC, CIP; mechanical compression joints 4 ft both sides of crossing

1 ft = 0.3 m
*from

The St. Petersburg Example. St. Petersburg, too, has taken safeguards to prevent cross-connections and misuse:

Piping: Distribution pipes for reclaimed water are identified with a vinyl adhesive tape imprinted with the words TREATED WASTEWATER. The city is presently working with a major manufacturer of PVC piping to develop a tan-colored pipe for conveying the reclaimed water.

Hydrants: Hydrants fed by the reclaimed-water systems are brown with a yellow stripe (Figure 2-23). These can be operated only with special tools that are available to designated public-utility personnel and the fire department. Hydrants fed by potable water are silver in color.

Valves: Valve boxes located along the reclaimed-water system are of a different shape than those along the potable system, and these are imprinted with the words TREATED WASTEWATER.

Meters: Meters for use in the reclaimed-water system are of a different make than those in the potable system. Meters for the nonpotable and potable systems, and the spare parts for these meters, must be kept segregated in Meter Maintenance.

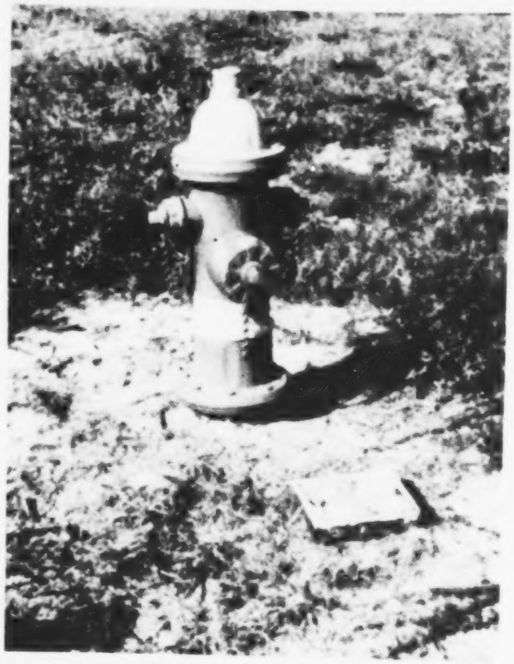


Figure 2-23. Reclaimed-water hydrants in St. Petersburg, Florida are painted brown with a yellow stripe (above), while potable-water hydrants are silver in color.

- All piping, valves, and outlets should be color-coded or otherwise marked to differentiate reclaimed water from domestic or other water. Where feasible, differential piping materials should be used to facilitate water system identification.
- All reclaimed water valves, outlets and sprinkler heads should be of a type that can be operated only by authorized personnel. Hose bibbs are not permitted on reclaimed-water distribution lines, in order to preclude the use of hoses and the likelihood of increased public exposure.
- Where reclaimed water is being used for recreational ponds and lakes, adequate means of notification should be provided to inform the public of this fact. Such notification should include the positioning of conspicuous warning signs with proper wording of sufficient size to be clearly read.
- Adequate measures should be taken to prevent the breeding of flies, mosquitoes, and other vectors of public health significance during the process of reuse.
- Operations of the use area facilities should not create odors, slimes, or unsightly deposits of sewage origin.

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The Economic Issues 3

The potential value of reclaimed water depends primarily on its assured availability (at a quality high enough to permit its use) and on its cost as compared to the cost of freshwater. In this chapter, we are concerned with:

- Establishing the present and projected unit costs of freshwater to the potential local users of reclaimed water, and
- Comparing these freshwater costs to the estimated cost of reclaimed water.

Estimating the Costs of Freshwater Supply

PRESENT COSTS

Water purveyors can provide you with present costs of water, usually expressed in dollars per thousand (or million) gallons. Present costs for potable water range from about $0.40 to about $1.00 per 1000 gallons for high-volume users in typical municipalities across the country. Unit costs are usually higher for smaller municipalities. This cost includes both amortized capital, if bonds or indebtedness are not retired, and operation costs.

The capital costs should include both depreciation and interest. Depreciation is the actual cost of a facility divided by its useful life. Interest costs are those which the utility must pay for its bonds. Operating costs include labor, maintenance and materials for each functional area. The major functional areas[1] are:

- **Acquisition:** may include the water-supply source, a large storage reservoir and transmission system, including pumping stations.
- **Treatment:** may include water-treatment facility.
- **Distribution:** may include multiple storage tanks and distribution system, including pumping stations.

Other costs, such as administration and customer services, should also be included in the present cost of water.

PROJECTED COSTS

Probably the best way to determine future water costs is to interview the official responsible for water supply, although information might also be available in a comprehensive water-supply planning document or water-rates study, if such has been completed.

Certain trends are apparent. Many communities are facing prospects of increasingly expensive water-supply development. In addition, water costs will undoubtedly increase as communities upgrade water treatment to meet the primary drinking-water standards promulgated by the EPA in June 1977. Additional EPA regulations governing levels of trihalomethanes (THMs) and granular activated-carbon treatment for removal of synthetic organics were proposed in 1978 (final regulations controlling THM levels were promulgated in November 1979); and the total national capital cost of meeting the proposed amendment's treatment requirements has been estimated by EPA at greater than $600 million.[2]

Costs will increase most markedly for smaller water-supply systems, which are likely to have more water-quality problems[3,4] due to:

- lower levels of treatment currently provided,
- inadequate maintenance of treatment equipment,
- badly maintained distribution systems, and/or
- absence of economies-of-scale.

Clark[5] recently examined the unit costs of six small (less than 1 mgd) water utilities and the cost increase each would face, in order to provide additional treatment necessary to comply with the Safe Drinking Water Act. Costs were shown to increase from an average of about $0.70/1000 gal. to $1.70/1000 gallons.

In a national survey of approximately 1,000 water purveyors serving a combined population of 18 million, the water-supply quality in 16 percent of the systems was found to fail **mandatory** requirements under the Safe Drinking Water Act, and another 25 percent were found to fail the recommended requirements.[6]

CASE STUDY:
Market Assessment in Walnut Valley

A reclaimed-water distribution system planned in 1979 for Walnut Valley, California, would distribute reclaimed water from the Pomona Water Reclamation Plant through 20 miles of pipeline for use by industries and for irrigation of golf courses and municipal grounds in the area. As part of the planning to date, a year-long market assessment was completed both to identify and arouse interest among the system's potential customers, and to focus in on what costs the customers would incur in converting to the reclaimed-water system.

Initially, the Walnut Valley Water District reviewed more than 15,000 customer records, in order to identify those customers using an average of more than 1.15 acre-feet per month. The District had determined that a user at this cutoff level could save $1,033 per year (assuming purchase of reclaimed water at $75 per acre-foot less than potable-water costs), a savings sufficient to justify for most industries an initial investment of $2,300 to tap into the reclaimed-water system (say, 100 feet of pipe plus a backflow-prevention device).

As the screening of potential customers was continued through initial contacts and discussions, the District found that price concerns were paramount among these water users as they considered committing their enterprises to use of reclaimed water. The marketing study team tried to determine what minimum savings over potable-water costs would be acceptable to the users. The potential savings were formulated as

$$S = \frac{C}{D \times N}$$

where:

S = required minimum savings in dollars per acre-foot;

C = user's internal capital investment;

D = user's demand in acre-feet per year; and

N = number of years in which investment is to be recovered.

Obviously, the degree of capital investment a potential user could commit to is linked directly to the minimum savings that that user could expect to achieve over potable-water costs. The greater the savings offered, the greater the capital investment each user could make, and the greater his demand could be. Based on these savings-demand relationships, the District was able to formulate a pricing policy attractive enough to draw firm commitments from more than 20 potential end users. The District set the price to be at least $40 per acre-foot less than the price for potable water (below this level, demand would drop rapidly, while only at twice that savings would many additional large users be attracted). Given the current potable-water costs of $131 to $200 per acre-foot, the price of reclaimed water would be sufficient to recover all capital and O&M costs and still provide a margin to finance future system expansion.

Source: Bales, R.C., E.M. Biederman, and C. Arant. Reclaimed-Water Distribution System Planning—Walnut Valley, California. In: Proceedings of the Water Reuse Symposium, Vol. 3. AWWA Research Foundation, Denver, Colorado, 1979. pp. 1663-1679.

Estimating the Costs of Reclaimed Water

The cost of reclaimed water can be divided into four principal components of capital and operations-and-maintenance (O&M) expense:

- Costs for additional treatment, if required (under the assumption that costs of treatment to meet a discharge requirement itself are rightfully allocated to the sewage-treatment and disposal function);
- Costs for conveyance/distribution of the effluent or reclaimed water;
- Costs for storage, if necessary; and
- Costs for monitoring reclaimed-water quality.

Having identified and estimated these components of total cost, you can compare the costs of potable water—the existing freshwater supply—to the estimated costs of reclaimed water. This comparison can provide some indication of whether or not reclaimed water will be competitive with the freshwater supply. By no means does this represent a definitive statement of the economics of reuse, however, nor should it form the sole basis of your subsequent decision-making.

Above all, you should be aware that the estimated unit cost of reclaimed water developed by the methods presented in this chapter bears no essential relationship to the prospective user's cost for tying into and using the reclaimed-water system. On the one hand, the user faces potential "penalty costs"[7] that can include costs of:

- on-site hookup to the nonpotable system;
- facilities for monitoring and adjusting water quality;
- additional treatment, if this is to be provided by the user;
- repiping for dual systems onsite;
- steps to assure worker safety;
- changes in normal practice: e.g., restricted access to irrigated lands, use of higher volumes of water to control salinity in the root zone (irrigation) or to compensate for poorer quality in recirculating cooling system (industrial), choice of different crop types or planting patterns; and
- possible need to increase return-flow control measure (irrigation) or waste-disposal steps (industrial).

Other "penalty costs" might be incurred by the community as a whole. For example, where local streamflow consists primarily of effluent from wastewater-treatment facilities, diversion of the effluent for reuse purposes not only would cause significant damage to stream habitats but also would deprive downstream users of the flow.

On the other hand, the community as a whole might realize so substantial a benefit from instituting a nonpotable reuse program that it will choose to finance the system in a way that keeps the users' total costs competitive with their costs for using freshwater (measures to accomplish this are among the financial issues discussed in Chapter 5). This community benefit can be of direct economic importance—such as obviating the need for funding expensive wastewater-treatment facilities to meet stringent discharge standards, or eliminating the need for costly new water development or importation—or of significance that is not directly economic, such as assuring an adequate potable supply in a water-short area.

The user, too, can gain benefits from use of reclaimed water: for an industrial user, this benefit might be the assurance of a reliable and adequate water supply (we have cited in Chapter 4 the examples of a manufacturer in El Paso, Texas, and a power company in Gillette, Wyoming), while for an irrigation user, one benefit could be the nutrient value— estimated at up to $30 per acre-foot—of the reclaimed water. Clearly, the true costs and benefits of reuse—to both the community and the user—are situation-specific. While detailed analysis of these costs and benefits lies beyond the scope of these *Guidelines*, you should be aware of the range of cost/benefit issues and trade-offs that should be quantified, to the extent possible, and evaluated closely in any feasibility study undertaken as you move toward plan implementation. A valuable document now available to support detailed economic and financial analysis is the State of California's *Interim Guidelines for Economic and Financial Analyses of Water Reclamation Projects*.[8]

The "reconnaissance-level" reuse cost estimates developed in this section are derived from generalized cost curves. Appendix C includes a discussion of the basis of costs and methods of converting capital costs to equivalent annual costs. An *Engineering News-Record* (ENR) Construction Cost Index of 3000 is used to develop these costs.

Obviously, the economic conditions of a particular area will influence cost-effectiveness of a specific local reuse scheme. Following reconnaissance-level analyses and preliminary screening of potential users and project alternatives, cost analysis of alternatives selected for detailed evaluation should be based on the detailed design of systems and on recent, local bid prices; in these *Guidelines*, however, we have used national average construction costs to support preliminary estimates.

Components of the total reclaimed-water costs are presented in these *Guidelines* as for a system that has the additional treatment steps first, followed by conveyance and storage. This sequence, which follows that practiced at Irvine Ranch Water District, is illustrated in the example case presented in this chapter. Actually, other sequences can be employed, and their selection will depend on local conditions. Several industrial reuse projects involve conveyance of secondary effluent to a storage pond, followed by treatment prior to reuse. Other installations, such as that in St. Petersburg, Florida, store treated reclaimed water on-site prior to distribution.

ADDITIONAL WASTEWATER TREATMENT COSTS

Based on the potential users' water-quality requirements as discussed in Chapter 2, you can determine what additional treatment steps might be required to reclaim water for your selected reuse market(s). The cost of additional treatment or advanced-treatment systems can then be estimated. In this section, we have provided cost curves for additional-treatment unit processes capable of supporting most of the different reuse functions discussed in these *Guidelines*. Table C-1 in Appendix C shows the equation of the cost curves and the coefficients and exponents of each curve. Design criteria are based on conventional practice, actual installation, and manufacturer's recommendations.

If possible, you should use locally-developed cost information as a basis for developing your own estimates, or at least for adjusting the estimates you obtain from these cost curves. Local information is bound to be more accurate than generalized cost data. Useful information might be found in local or regional wastewater-facilities feasibility studies, in facilities plans, and from cost-information records maintained at recently-constructed water- and wastewater-treatment facilities in your area.

The cost curves (Figures 3-1 to 3-10) present a range of flows from 10,000 gpd to 100 mgd, although costs are probably most accurate in the range of 1 to 50 mgd. To use the curves, you first must determine the design flow and the type of unit processes that will be employed, using information presented in Chapter 2. The design flow can be determined on the basis of average daily flow (user demand) times a peaking factor that will depend on peaks in user demand, as discussed in Chapter 2 (keeping in mind that some equalization can be provided by differing demand patterns among various system users), and on the volume of reclaimed-water storage being provided.

From this information, you can estimate the approximate costs of treatment required for a reuse system. Finding your projected design flow on the cost curve's abscissa, refer to the left-hand ordinate of the curve to obtain capital costs in units of millions of dollars. Similarly, use average daily flow on the abscissa to find annual operations-and-maintenance costs in units of millions of dollars on the right-hand ordinate. Design parameters and cost equations for the unit processes, and definition of the components of capital and operating costs, are all presented in Appendix C.

The treatment processes shown in this section have all been used successfully at many wastewater reuse facilities. Under the current EPA Innovative and Alternative (I/A) Technology program, these processes would be considered conventional. The I/A solutions must be considered in all planning efforts after September 30, 1978 receiving construction grant funds.

An **alternative** technology is a proven method of treatment that provides for reclaiming and reusing water, productively recycling wastewater constituents, eliminating the discharge of pollutants, or recovering energy. An **innovative** technology refers to a new and promising technology that has been developed but has not been fully proven under the circumstances of its intended use.[9] EPA provides economic incentives to promote I/A , and these are discussed in Chapter 5. Since most municipal reuse planning involves the EPA construction grants program, the I/A technologies will be evaluated along with the methods presented herein.

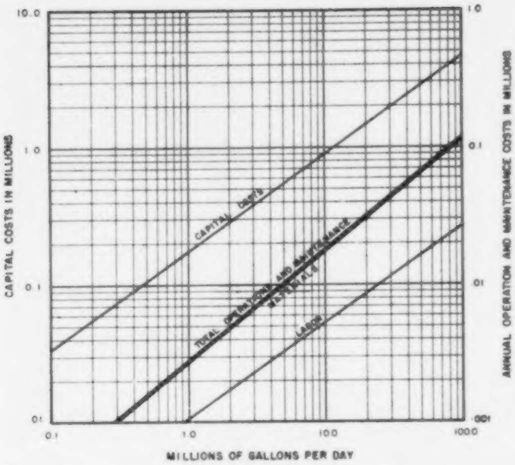

Figure 3-1. Costs of Coagulant Addition and Flocculation

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

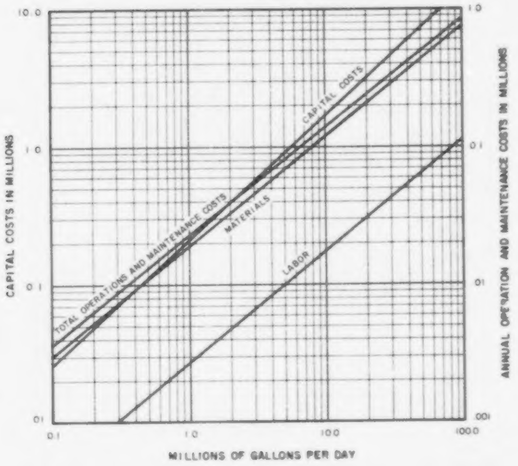

Figure 3-2. Costs of Filtration

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

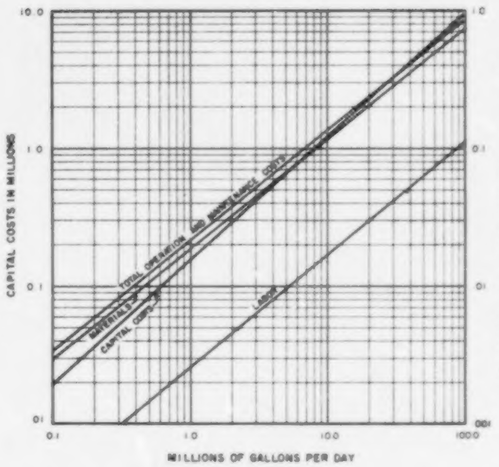

Figure 3-3. Costs of Sedimentation

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

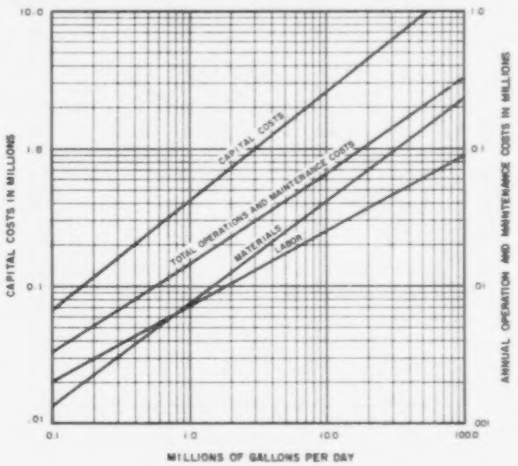

Figure 3-4. Costs of Separate Nitrification

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

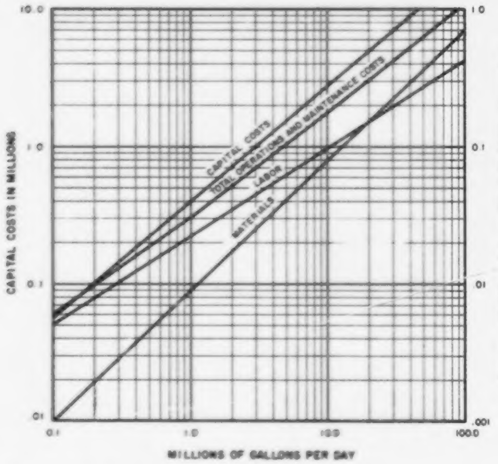

Figure 3-5. Costs of Two-Stage Lime Treatment

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

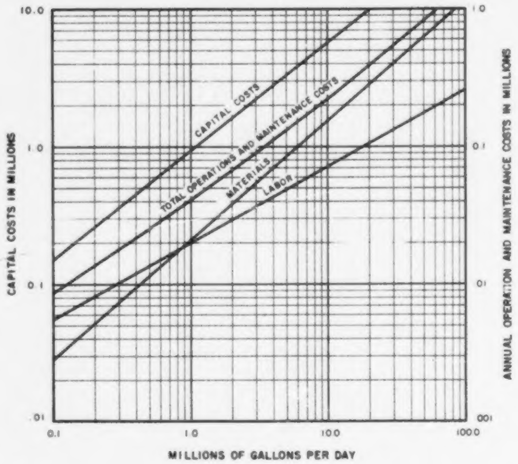

Figure 3-7. Costs of Carbon Adsorption

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

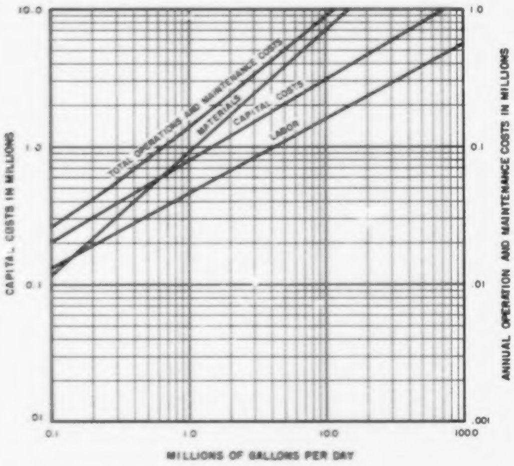

Figure 3-6. Costs of Lime Recalcination

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

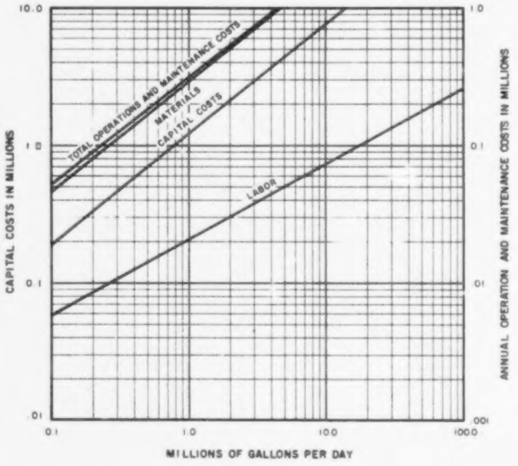

Figure 3-8. Costs of Reverse Osmosis

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

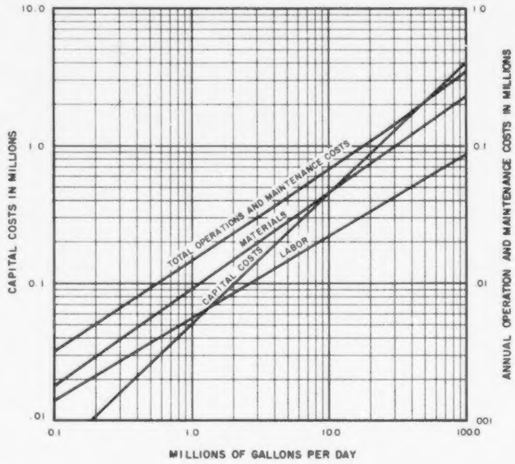

Figure 3-9. Costs of Chlorination

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

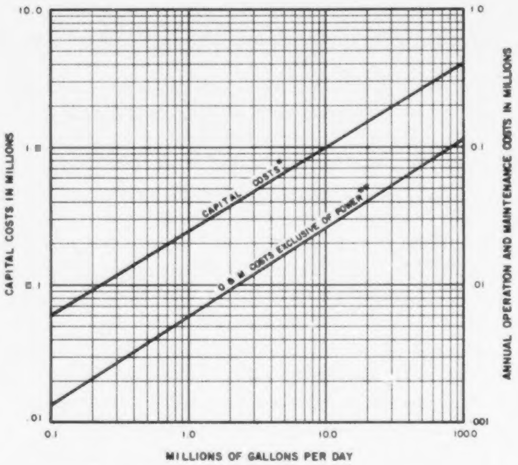

Figure 3-12. Costs of Pumping Stations
*based on total size of station (use peak flow rate)
**assume 100-ft TDH (add or subtract 15% for each 50 feet of TDH in 50—250 foot range)
ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

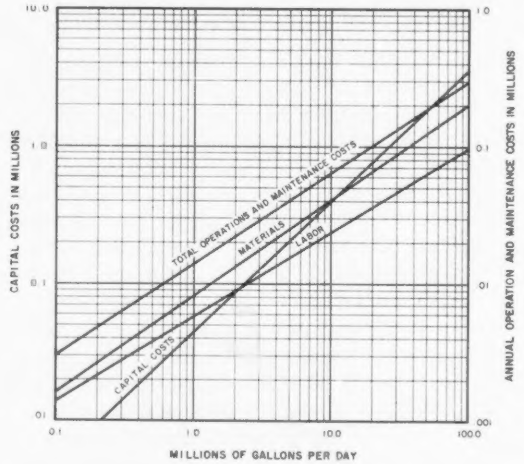

Figure 3-10. Costs of Dechlorination

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

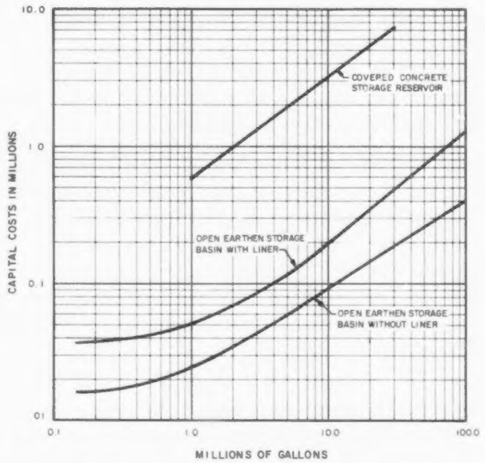

Figure 3-14. Costs of Storage

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

CONVEYANCE/DISTRIBUTION COSTS

No single factor is likely to influence the economics of reuse more than the conveyance or distribution of reclaimed water to its point of reuse. Conveyance systems range from straightforward systems serving one or more large users to complex systems involving distribution to many individual users. An example of the first type can be found in Denton, Texas, where some 1.5 mgd of secondary effluent is pumped two miles through an 18-inch diameter force main to a storage pond located adjacent to the city's power-generating plant. The water is subsequently treated and used as make-up water in cooling towers.[10] An example of the second type of system is that managed by Irvine Ranch Water District in California. There, reclaimed water is pumped to two reservoirs located four and eight miles, respectively, from the wastewater-reclamation plant. Water is distributed through some 30 miles of force mains for use in agricultural and landscape irrigation, serving a residential area with a population of about 50,000.[11]

To determine what conveyance system is most economical for your reuse plan, you must evaluate the trade-off between initial capital costs and operations-and-maintenance costs over the life of the project. For the "straightforward" system (the example we used above was Denton, Texas), you can easily obtain a "reconnaissance-level" estimate of costs for your conveyance system components using the steps described in detail below.

Capital Costs for Force Mains. We suggest at least two ways by which to determine a suitable—not necessarily optimum—pipe diameter for effluent conveyance. First, studies have shown that the average velocity for cost-effective water mains is approximately 4 ft/sec.[12] Using this velocity, one can derive the following equation expressing pipe diameter in terms of flow:

$$D = \sqrt{0.32Q} \quad (1)$$

where: D = pipe diameter in feet, and
Q = flow in cubic feet per second

In each community, the actual **optimum** (most economical) force main diameter may vary according to local operating expenses. Consider the relationship between capital and operating costs shown in Figure 3-11, illustrating the trade-off between initial capital costs and operations-and-maintenance costs over the life of the project.[4] Selection of smaller pipe diameters results in larger friction heads, requiring larger pumps and more energy. Increase in pipe diameter gives smaller friction heads and so a decreasing energy cost, but at a steadily-increasing capital cost. Summing the capital and O&M costs over a range of increasing diameter yields the curve at the top. Where this curve "bottoms out," total annual costs are at a minimum, corresponding to the optimum force-main diameter. When local energy costs increase more rapidly than other costs, annual O&M costs will be higher for a given pipe diameter, displacing the total-cost curve to the right; in such situations, the optimum pipe diameter will be larger.

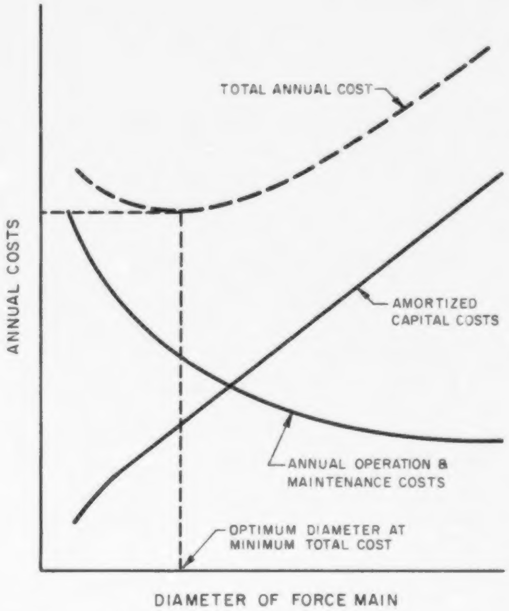

Figure 3-11. Relationship of Annual Conveyance Costs to Diameter of Force Main

ENR = 3000
Metric conversion: 1 mgd = 3,785 cubic meters per day

Having determined the suitable or optimum force-main diameter (D), refer to Table 3-1 to estimate the total capital costs of force mains in dollars-per-linear-foot. To figure total capital costs, you need to determine the conveyance route and end-point elevations along the route, for each potential user. This information can be lifted from the USGS map used for locating your local reclaimed-water sources and potential user sites. There is no need to optimize force-main routing; plotting of a realistic conveyance route—generally over existing roadway networks—between source and potential user will prove satisfactory for reconnaissance-level analysis.

Similarly, USGS contours will provide sufficient detail to estimate the difference-in-elevation (static head) that must be overcome in pumping.

Capital Costs for Pumping Stations. Knowing your average daily flow and design peaking factor, you can determine capital costs of pumping. Pumping stations for reclaimed water are usually designed for delivery of the maximum daily flow. If large storage facilities are part of the conveyance system, peak flow rates can be adjusted. Providing capacity for several months' storage prior to reclamation either at the wastewater-treatment facility or at the site of reuse will permit a smaller pumping station and conveyance-pipe size. Figure 3-12 shows the costs for pumping stations. For an average daily flow of 1.5 mgd and a peaking factor of 2, you would enter the curve at 3 mgd and obtain a cost of approximately $475,000. Capital costs assume a 100-ft total dynamic head (TDH). Approximately 15 percent should be added or subtracted for each 50 feet of TDH in the range of 50 to 250 feet TDH.

Operating Costs for Pumping Stations. Annual operations-and-maintenance costs can be divided into two major groups: power, and labor-and-materials. Figure 3-12 shows annual O&M costs exclusive of power. These costs are based on the total size of the station, and, therefore, you should find the annual costs based on the peak flow rate. Power costs can be estimated on the basis of horsepower required at average daily flow, taking into account both pump and motor efficiencies. Use the following formula to calculate horsepower (hp):

$$hp = \frac{Q \times TDH}{2800} \qquad (2)$$

where: Q = average daily flow in gallons per minute;
TDH = total dynamic head in feet (static head plus friction head at average daily flow); and
2800 = factor which takes into account a combined pump and motor efficiency of 70 percent.

TDH is the sum of static head and friction head. **Static head** is simply the difference in elevation (in feet) between the pumping station and the proposed point of reclaimed-water reuse—all of which you have plotted on USGS or other contour maps—plus the selected system pressure. Friction head losses for various pipes and flows can be determined from tables and graphs available in standard hydraulic texts. In Figure 3-13, we have presented one such graph, which is based on a conservative Hazen-Williams roughness coefficient of 100. Draw a straight line connecting your proposed flow (gpm) to the suitable pipe diameter (in inches) determined above. Extending this straight line to the line for head loss (in feet of water per 1,000 feet) provides an approximation of **friction head**.

Table 3-1. TYPICAL CAPITAL COSTS OF FORCE MAINS INCLUDING INSTALLATION

Diameter of Force Main (inches)	Cost per Linear Foot (dollars)
4	$ 18
6	21
8	27
10	33
12	37
14	47
16	54
18	64
20	70
24	86
30	125
36	162

ENR = 3000
1 ft = 0.3 m

Having calculated pump horsepower requirements, you can estimate annual power costs using Equation 3:

Annual Power Cost (c) =

$$hp \times .075\ kW/hp \times hrs/yr \times \$/kW\text{-}hr \qquad (3)$$

where the unit cost for power can be adjusted to local rates, and hrs/yr can be estimated according to proposed usage, as in the example.

Distribution System Costs. When the proposed reuse scheme involves a more complex distribution system serving residential areas for lawn irrigation, for example, more detailed engineering analysis will be necessary. If the application is for nonpotable residential use, you can design the system as a municipal water-supply distribution system. It is best to estimate total system length based on a street-by-street layout.

It has been found that the length of water mains is usually a function of population density. You can roughly estimate water-main length by the following formula:[13]

$$L_m = 125\ P^{-0.46} \qquad (4)$$

where L_m = length of main in miles per 1,000 population
P = population density (persons/square mile).

For example, a municipality of 2,000 persons residing in one square mile could be serviced by about 7.6 miles of water mains. Based on an average force-main diameter of eight inches (typical of urban systems) and costs of $27 per linear foot as presented in Table 3-1, capital costs for this system would be about $1,100,000.

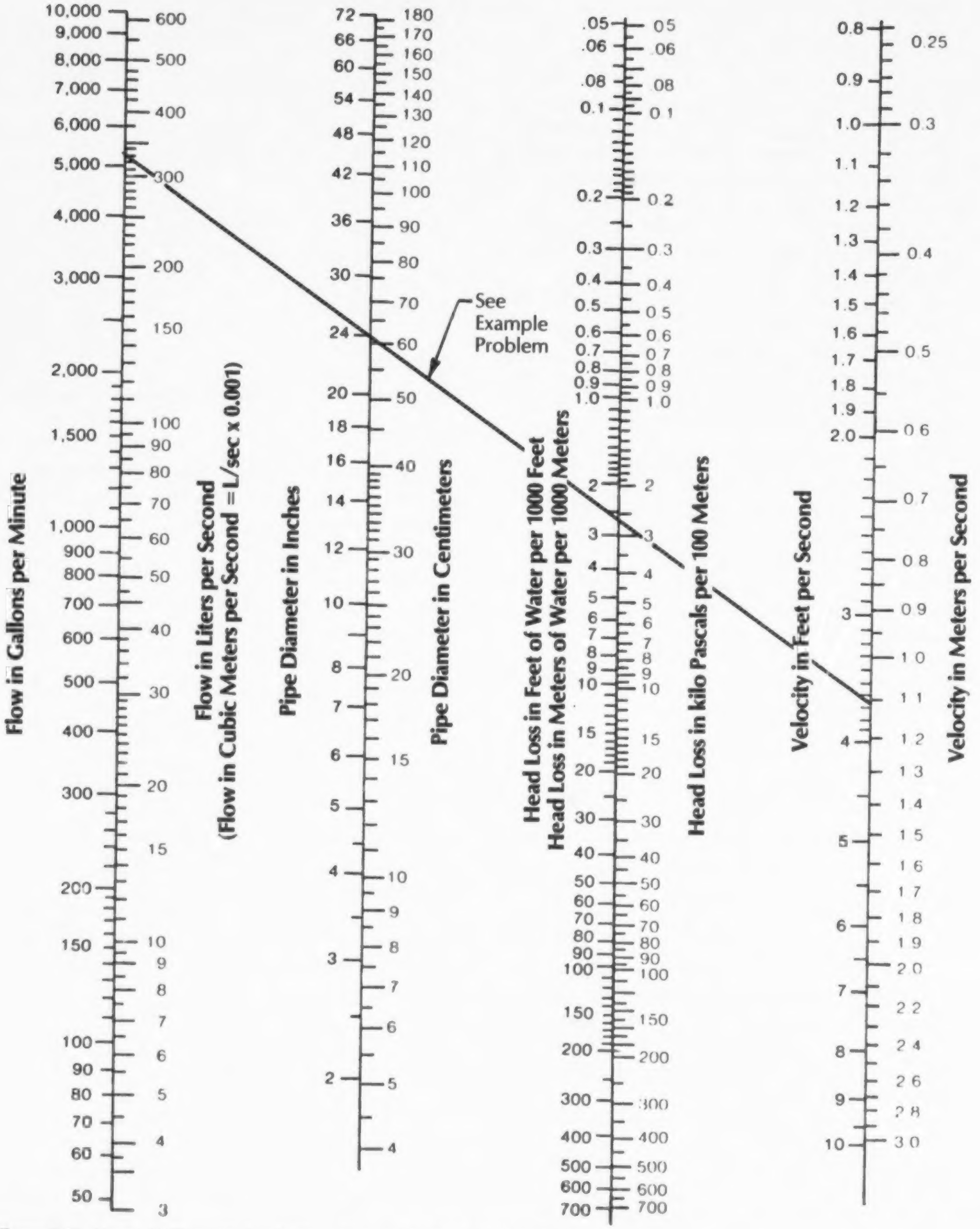

Figure 3-13. Hazen-Williams Hydraulic Flow Charts with C = 100 (Adapted from Ref. 15)

STORAGE COSTS

Providing for storage of reclaimed water at the point of reuse can cut distribution costs, by making it possible to reduce the diameter of distribution piping. When storage is available, there will be no need to size for the instantaneous peaks in reclaimed-water demand.

The cost-effectiveness of providing storage will depend on the availability and cost of land for the required storage, and on the need to provide any additional treatment (aeration or disinfection) during or after the holding period. Properly designed, covered storage facilities will prevent degradation in water quality and can actually improve water quality through physical and biological processes. Open storage facilities, on the other hand, might result in degradation and requirement for retreatment.

Figure 3-14 presents costs for two general types of storage facilities: open earthen basins and covered concrete storage reservoirs (costs for steel-storage tanks would fall between those for lined earthen and concrete reservoirs). Open earthen storage basins are appropriate for use in agricultural-irrigation and industrial reuse systems. These basins can be either lined or unlined, depending on local soil conditions. Covered concrete storage reservoirs of the type commonly used for potable-water supply should be used if the reclaimed water is being delivered in a dual distribution system. Use of covered reservoirs will reduce chlorine losses and algae problems and will help to maintain the quality of the reclaimed water in the distribution system. In St. Petersburg, Florida, for example, the city is planning to install covered service reservoirs at three future reclamation plants, after having experienced problems with growth of algae in an open storage reservoir for reclaimed water.[14]

GUIDELINES FOR THE ECONOMIC EVALUATION

Having determined, respectively, the costs of freshwater and of reclaimed water, you can now compare these costs in order to weigh the economic aspects of a reuse project (see example computations).

The reclaimed water must be available to potential users at reasonable cost, but there are many other economic and noneconomic factors that should be evaluated. A local freshwater cost that is lower than reclaimed water would not **necessarily** imply that water reuse could not be economically effected, nor, by the same token, would a higher freshwater cost necessarily imply that reclaimed water would be highly competitive. Your decision to proceed with reuse planning does not hinge solely on economics. Some of the noneconomic factors discussed in the next few chapters may in themselves allow you to make decisions on reuse options in your community.

Some of the economic aspects that may be difficult to quantify in a preliminary reuse study include the following:

- Costs of additional wastewater treatment to meet high discharge standards if water is not reclaimed;
- Costs for future capacity in interceptors or wastewater-treatment facilities;
- Additional costs for customers required to retrofit for installation of a dual distribution system;
- Cost of increased water use that might be necessary for irrigators to flush out minerals accumulating in the root zone, and the value of nutrients in reclaimed water that is used for irrigation purposes; and
- Costs of increased system monitoring and administrative functions required for two grades of water.

These factors should be kept in mind while evaluating the economic feasibility of various reuse alternatives. As a first cut, you might screen out all projects that are more than 50 percent or 100 percent greater than the projected potable-water costs, and then proceed with more detailed and specific economic and financial evaluations of the remaining project alternatives.

CASE STUDY:
An Example of Penalty Costs

User "penalty costs," such as those for hookup to the reclaimed-water system and for any repiping necessitated by the system, can be quite substantial. When the nonpotable system was being installed by the Irvine Ranch Water District (IRWD) in Irvine, California, the nonpotable piping was connected to an existing landscape-irrigation system. In one small system, the runoff fed a small stream and decorative pond. Since the IRWD permit did not allow any runoff, it was necessary to take corrective action. The IRWD found that the least expensive solution would be to reconnect portions of the irrigation system to the potable supply, despite the higher price of that water, rather than to modify the irrigation system in order to reduce runoff. In this case, the expense of redesigning and altering the irrigation system to permit safe use of reclaimed water represented a user penalty cost (Matthew Lovein, personal communication).

Example of Estimating Costs

Basic Information. A 10-mgd biological secondary-treatment facility is located in a suburban residential community near an extensive regional park. From a preliminary market analysis, it has been determined that 5 mgd could be utilized for irrigation of a golf course, playgrounds, and sports areas, and for general landscaping needs. The reclaimed water would be pumped over a distance of 10,000 feet to storage facilities that are 70 feet higher in elevation than the pumping station.

TREATMENT

Location and Type of Treatment. The municipality has determined that it would operate the reclamation facility at the site of the existing secondary plant. Based on water-quality standards required by the state, the recommended treatment process for urban distribution systems would include coagulant addition, flocculation, filtration and disinfection.

Use of Cost Curves. A table showing each unit process, the capital, amortized, and operations-and-maintenance costs is shown below. To follow the example through, locate and use three cost curves: coagulation (Figure 3-1), filtration (Figure 3-2), and disinfection (Figure 3-9). Amortized capital costs are computed by multiplying capital costs by 0.10. This factor is based on a 15- to 20-year service life of facilities, at an interest rate of approximately 7 percent. Appendix C presents a detailed analysis by which you can amortize capital costs with different service lives. However, this type of cost-effectiveness analysis will not affect total cost significantly and is not warranted in reconnaissance-level reuse planning.

Unit costs are determined by dividing the annual cost ($387,000) by the amount of reclaimed water used in one year (1,825 million gallons), or approximately $210 per million gallons.

CONVEYANCE

Select Peak Factor and Size Force Main. A peaking factor of 1.5 is used to allow for pumping during two shifts per day, if desired at the wastewater reclamation facility. The peak flow rate is, therefore, 7.5 mgd (5 mgd x 1.5) or 11.6 cfs. Pipe diameter for preliminary analysis is calculated using equation 1:

$$D = \sqrt{.32\,(11.6)} = 1.92 \text{ ft or } 24 \text{ inches}$$

Determine Power Costs. To determine horsepower, calculate the friction head from Figure 3-13. At an average flow rate of 5 mgd (or 3,470 gpm) and a pipe diameter of 24 inches, the friction head is 1.3 feet per 1,000 feet. The TDH is calculated as follows:

$$TDH = 70 \text{ ft (static head)} + 1.3 \text{ ft}/1{,}000 \text{ ft} \times 10 = 83 \text{ ft}$$

TOTAL TREATMENT COSTS

Unit Process	Capital Cost	Amortized Capital	Annual O&M	Total Annual Cost
Coagulation and Flocculation	$ 540,000	$ 54,000	$ 105,000	$ 159,000
Filtration	890,000	89,000	80,000	169,000
Disinfection	200,000	20,000	39,000	59,000
TOTALS	**$1,630,000**	**$163,000**	**$ 224,000**	**$ 387,000**

Horsepower can then be calculated from equation 2 as follows:

$$hp = \frac{3470 \text{ gpm} \times 83 \text{ ft}}{2800} = 103$$

Annual power costs are calculated using equation 3:

$$C = 103 \text{ hp} \times 0.75 \text{ kW/hp}$$
$$\times 365 \text{ days/yr} \times 24 \text{ hrs/day} \times \$0.05/\text{kWhr} = \$33{,}835$$

Determine Total Operating and Capital Costs. Operating costs exclusive of power and capital costs are determined from Figure 3-12 by entering the peak pumping-station capacity. Force-main costs are based on Table 3-1. Force mains may be amortized by using a factor of 0.8, which is approximately a 40- to 50-year service life at 7% interest. For a 24-inch-diameter force main, the unit cost is approximately $86 per linear foot. A table similar to that shown below can be set up to record these costs. Unit costs are $214,000/1,825 million gallons, or approximately $120 per million gallons.

TOTAL CONVEYANCE COSTS

Pumping Station (Capital Costs $850,000)	
Amortized Capital Costs	$ 85,000
Annual Power Cost	34,000
Annual Operating Cost	21,000
Sub-Total	**$140,000**
Force Main (Capital Costs $860,000)	
Amortized Capital Costs	$ 69,000
Total Annual Cost	**$209,000**

STORAGE

Using Figure 3-14, it is shown that a 5-mgd covered storage reservoir would cost about $1.9 million and would be amortized at approximately $150,000 per year over a 40- to 50-year period ($1,900,000 x 0.08).

SUMMARY OF COSTS

Costs from the example are summarized below:

Component	**Annual Costs**
Additional Treatment Facilities	$387,000
Conveyance System	209,000
Storage Facilities	150,000
Total	**$746,000**

Therefore, unit costs are $746,000/1,825 mg, or $410 per million gallons.

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The Legal and Institutional Issues

4

In simplest terms, the legal and institutional issues are the issues that tell you what you may and may not do and, in the case of the former, how you must do it.

Any reuse program operates within a framework of regulations, enabling powers, and financing constraints that must be addressed in the earliest stages of planning. Study of these legal and institutional issues could help you to uncover program funding sources you hadn't been aware of, or to identify the best operating structure for your water-reuse program. You might find that local regulations or state laws constrain or preclude efforts at water reuse, or you might find that changes in local policy or state legislation are necessary to permit or promote reuse. For example, in Contra Costa County, California, an ordinance was enacted to state that potable water could not be utilized for certain uses if reclaimed water were available.[1] At the Irvine Ranch Water District, industrial wastewater pretreatment provisions were enacted to protect the quality of the district's treatment-plant effluent.[2]

Most likely, unless you are in the western and southwestern portions of the country where most existing water-reuse programs are being operated, you will be hard-pressed to perceive any comprehensive, coherent approach to water reuse in your state. You will likely discover that many agencies recognize that they should have some responsibility relating to water reuse but that they are unsure of exactly what is their authority or responsibility.

This chapter provides an overview of the legal and institutional issues. In it, we discuss:

- The legal issues associated with reuse;
- The organizations involved, the regulations promulgated by each, and the review procedures used by each; and
- General steps that you should follow throughout implementation of your reuse project.

The chapter provides a general approach to help you identify all of the major issues associated with water reuse. Specific parts of the approach might not apply directly to issues in your state, but they should still support an understanding of primary legal and institutional issues. This chapter is not designed to allow you to render judgments that your municipal legal counsel should make; it is simply intended to describe the type of issues with which you should be concerned when assessing the feasibility of water reuse.

Identifying Legal Issues

The legal issues warrant careful review. It is necessary to check:

- **State Statutes.** This legislation will say what can and cannot be done, what is to be regulated, and who is to administer such legislation.
- **Enabling Legislation.** This legislation in particular will state what a municipal entity can do.
- **Water Rights Law.** This will allow you to determine what your legitimate claim is upon the water you intend to use.
- **Franchise Rights.** This will indicate whether some other entities have the exclusive authority to provide water for public use.
- **Case Law.** The court decisions relating to the development of municipal water supply will allow you to understand the courts' interpretation of any especially controversial laws, including interpretations of legal liability.

CASE STUDY:
Contra Costa County: Institutional Issues in California

It took Contra Costa County about ten years to resolve all of the institutional issues associated with water reclamation and reuse there. Facilities now are essentially complete, and a number of local industries will soon be using reclaimed water for cooling purposes (Figure 4-1).

The project's two prime participants, the Sanitary District and Water District, initiated the project in the late 1960s, based on mutual need. The Sanitary District faced new regulatory requirements for expanded and upgraded wastewater-treatment facilities. The Water District found that the projected increase in demand for potable water—a large portion of the increase due to industrial use—would force development of new supplies and transmission facilities.

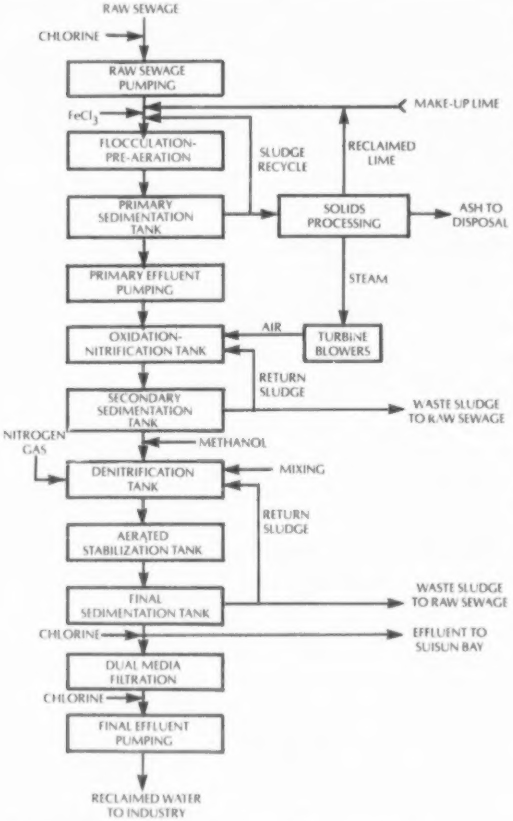

Figure 4-1. In Contra Costa County, the water-reuse program is a joint venture between the county's water and sanitation districts. The Sanitation District provides the Water District with an oxidized, filtered and disinfected water product (as shown above); the Water District treats the water additionally by sodium ion exchange before delivering it to industrial users. (Source: Industrial Reuse Complex at Concord, California, Water Reuse Highlights, AWWA Research Foundation, Denver, Colorado, January 1978. 119 pp.)

A feasibility study completed in 1969 contained the recommendation that the two Districts agree to carry out further studies on water reclamation, which had been found to be technically feasible. Other technical evaluations, completed concurrently, showed various pollution-control alternatives all to be very capital-intensive. In December of 1969, the Districts executed a Memorandum of Understanding in which each stated its explicit interest in reclamation and agreed upon a six-phase program towards implementation. The Memorandum represented the first tangible evidence that the Districts shared a common interest and level of cooperation in realizing reuse in Contra Costa.

During the next two years, reuse gained new impetus from federal and state agencies. Pilot-testing was funded by a research-and-demonstration grant from the Federal Water Pollution Control Administration (now EPA). The California Water Resources Control Board, in reviewing the Sanitary District's precertification report for WWTP improvements, insisted that more attention be given to reclamation and that the Water and Sanitary Districts negotiate a contractual agreement toward this end. Initially, the district boards stated their intent to negotiate, in order to keep the project alive; ultimately, and by unanimous votes, the boards adopted a negotiated contract. Three major problems remained:

- **Funding.** The Sanitary District obtained federal support through an amendment to the Water Pollution Control Act Amendments of 1972 that rendered the proposed project grant-eligible. The Water District adopted a pay-as-you-go approach, funding its capital requirements by increasing its water rates.
- **Quantities.** The State Board wanted the contract to stipulate what actual quantity of water would be reclaimed. The Sanitary District, too, wanted a minimum purchase commitment from the Water District, in order to cover the local share of construction. The Water District wanted to purchase only as much water as it could sell. The issue was resolved by identifying in the contract the reclaimed-water users and the amounts each would require.

- **Bureau of Reclamation.** The Water District had contracted with the federal Bureau of Reclamation for purchase of water, and the local Bureau office wanted to hold the District to the commitment, (a requirement that would have made the reuse project too costly). This problem, potentially the most serious of the three, was resolved by involving Bureau headquarters personnel in Washington, D.C. in the initial negotiations, thus gaining their support for the reclamation/reuse concept.

The potential industrial users showed considerable reluctance, at first, to commit to use of reclaimed water, particularly at the anticipated price and with the amount of additional treatment that would still be necessary. In addition, industry was concerned about discharge requirements for its waste cooling water. These issues were resolved by ordinance. The Water District stated that if reclaimed water were available for cooling purposes, canal water would not be sold for that purpose. The District also stated its intent to reflect in its use charge any costs assumed by the reusers for additional treatment of the reclaimed water. The bulk of reclaimed-water costs, however, will be spread among all water users in the district, as reclamation is seen to support a more general good. With reclamation, development of a new water source is not necessary. And the reclamation project is, after all, significantly less costly than developing the new transmission facilities that had been thought necessary in 1969.

STATE STATUTES

You should begin by checking the legislation relating to environmental and utility regulation for the state in which you are located; your municipal legal counsel will either possess or have ready access to a copy of the state statutes. New legislation at the state level can affect reuse opportunities. For example, it is expected that stringent water-quality monitoring requirements will be mandated by the State of California as reuse applications continue to expand in that state. Thus, as new legislation is enacted, it should be carefully studied.

Thorough understanding of state statutes will help you to avoid situations of tort liability, also. Most states have well-defined liability laws relating to defects in design and manufacture of products. Legal precedents exist for considering distributed potable water a product that is subject to these laws.[3] The municipal official planning to implement a program of water reuse must take direction, in assuring safety and reliability in the reclaimed-water system, from these liability laws. As noted in Chapter 2, the few state regulations that exist pertaining to quality, distribution and use of reclaimed water can serve only as a guide to minimum standards your program should meet. The potential for liability in case of system inadequacy or failure should prompt you to go well beyond the minimum.

Zeitzew has listed a number of steps that a municipal official should expect to take in implementing a reuse program.[3] These include developing an informed awareness of hazards that can accompany use of reclaimed water (Chapter 2), carrying of adequate liability insurance, selection of highly qualified design and operations personnel, careful monitoring of water quality—including monitoring of known hazardous substances not yet regulated by state statute, and development and maintenance of contingency plans and emergency backup procedures to assure system reliability.

Try to determine what is regulated or facilitated by the law, by whom, and how. The state statutes deserve careful review, but less effort need be devoted to federal legislation. The federal agencies' methods of regulation can easily be determined as you establish contact with those agencies.

ENABLING LEGISLATION

Enabling legislation will be found bound in the state statutes (just as are all the appropriate environmental laws) or within your own municipal code.

Allowable Operating Structures. You should survey the law to determine what are the best municipal organizations under which to operate a reclamation and reuse program. For example, even if the municipal wastewater-treatment service is permitted by law to distribute reclaimed water, it might make more sense to organize a reuse system under the water-supply agency or under a regional authority (assuming that such an authority can be established under the law). A regional authority could operate more effectively across municipal boundaries and could obtain distinct economies-of-scale in operation and financing advantages.[4] To form an authority, it might be possible to establish a new public entity under existing legislation, or it might be necessary to enact new legislation.

Your survey of enabling legislation should also determine if there are other incorporated entities that are allowed to distribute water; you might be able to anticipate possible conflicts among competing entities.

Financing Powers. In addition, you should make note of all the financing constraints that apply to each entity, yours as well as any other possible organization under which to operate. For example: Can it assume bonded indebtedness? What kinds of debt? To what limits? How must the debt be retired? How must the costs of operating the water-reclamation facility be recovered? What restrictions are there on cost-recovery methods? What kinds of accounting practices are imposed upon the entity?

Contracting Power. Finally, you should determine if there are any constraints on how and with whom you can contract for services. For example, can you now contract with other municipalities? Could you, under another operating structure? Are there severe political constraints—for example, do you need city-council approval, or can you operate quite independently of the municipal government? Can you participate in activities for profit, or is your responsibility strictly to provide services at cost?

In general, you should review the enabling legislation to see what you are able to do and what other governmental entities are allowed to do. This will help you to determine the most effective framework under which to provide reuse services.

Examples of Operating Structures. Obviously, many different types of institutional structures can exist. For example, the Irvine Ranch Water District in California is a self-contained entity. Under its original enabling legislation, it was strictly a water-supply entity, but in 1965 the state law was amended to assign it sanitation responsibilities within its service area (Figure 4-2). Thus, the District is in a good position to deal directly, as one entity, with potential users of reclaimed water, as well as to provide conventional potable-water and wastewater services.[2]

Where separate municipal services exist for water supply and wastewater, the water-supply entity has to deal first with the wastewater service before procuring reclaimed water-users. In Contra Costa County in California, this was the case. A reuse project was established as a joint venture between the County's water and sanitation districts. The Water District purchases reclaimed water from the Sanitation District and then treats and redistributes it to its users.[5]

In Los Angeles, the institutional arrangement is one step more complex. There, the Pomona Water Reclamation Plant is operated by the Los Angeles County Sanitation Districts (LACSD). LACSD sells reclaimed water to purveyors, including the municipal Pomona Water Department, which then resells it to a number of reusers.[6]

Conclusions. Existing or new enabling legislation can serve as the basis for any institutional arrangement that is constitutional. In general, the simpler the structure, the better. The Irvine Ranch Water District approach is preferred, even though it required new legislation to establish its combined responsibility. In Contra Costa, hurdles posed by having dual water and wastewater agencies were overcome contractually. (Even in this case, new legislation was required. Each district's board of directors adopted resolutions indicating their intent to work jointly.[5])

Figure 4-2. Irrigation of common residential areas at Irvine Ranch Water District in California. Amendment of state law in 1965 enabled the District to operate as a self-contained water-supply/sanitation entity within its service area. This approach can simplify implementation of a water-reuse program.

WATER RIGHTS

Water rights are an especially important issue. The water rights system can actually promote reuse measures, or it can pose an obstacle to reuse.

Water Rights Supporting Reuse. In the West, many users of reclaimed water have found it simpler to obtain and use reclaimed water than to obtain appropriated water from the state's water rights board—particularly since the freshwater appropriation would be designated a low-priority right and would be withdrawn in times of water shortages. In Odessa, Texas, the El Paso Products Company chose to purchase reclaimed water for cooling water and boiler make-up water because the reclaimed water is a more reliable source than the public or private water supply.[7]

A similar situation exists in Gillette, Wyoming, where the Wyodak Power Plant is utilizing reclaimed water as the primary source of water for all purposes except domestic supply. The power plant is innovative in itself; it is the world's largest air-cooled power plant. When the power company determined that it was uncertain whether the availability of surface-water sources could be relied on, it resorted to use of reclaimed water as an assured source of water.[8]

Water Rights as an Obstacle to Reuse. Water rights issues can constrain reclamation/reuse projects, because the law may impose on any water user certain requirements pertaining to the use and return of that water. It is true that few examples can be cited in which water rights issues actually precluded an otherwise viable project. Nevertheless, the issues effectively blocked, in Solano County, California, what would have been one of the largest reclamation/reuse projects yet attempted in this country. Unable to contract for new sources of freshwater, in 1975 the County began investigating the possibility of purchasing some 150,000 acre-feet per year of "advanced-secondary" effluent from a regional treatment plant scheduled for completion in 1981; the County planned to use the water for irrigation of 35,000 acres of farmland. Planning on the project moved ahead sporadically, but the problem of water rights surfaced as a significant obstacle: according to the state, most of the effluent rightfully "belonged" to the Sacramento/San Joaquin Delta, and significant environmental harm—increased saltwater intrusion from San Francisco Bay—would result if this water were removed from Delta flows for reuse purposes. In 1979, the State Water Resources Control Board halted project funding.

In other cases, it is possible that municipalities would lose a portion of their water rights if they decreased their water consumption. In some states, however, this problem is being remedied. For example, legislation has been proposed in California to provide that whenever water use decreases under an existing appropriation because use of reclaimed water has been substituted, the original water appropriation will not be lost.

Understanding Water Rights. Two general guidelines are offered. Expect water rights to be an issue if you are in a water-poor area and/or if the reclaimed water will be utilized in a consumptive fashion. These, ironically, are both conditions under which water reuse would be most attractive.

A water right is a right to use water. It should not be interpreted as a right of ownership. A "water right" allows you to divert and utilize a portion of the water; that right is accompanied, however, by the obligation to return the water in a manner that does not adversely affect others who also have a right to that water. The most basic doctrine in water-rights law is that you cannot render harm upon others who might have claim to the water.

There are two main systems of water rights—the **appropriative doctrine** and the **riparian doctrine.**

The appropriative rights system is found in most western states and in areas that are water-poor (California has both appropriative and riparian rights). It is a system by which the right to use water is appropriated—that is, it is assigned or delegated to the consumer. The basic notion is: first in time, first in right. In other words, the right derives from prior use. If you were using the water first, you have the most senior claim to that water. The senior users have a continued right to the water, and a junior user generally cannot diminish the quantity or quality of the water to them. Generally, appropriative water rights are acquired pursuant to statutory law; thus, typically, there are comprehensive water codes which govern the acquisition and control of the water rights.

CASE STUDY:
Water Rights Problems Turned to Opportunities

Resolving the water-rights issue proved to be the most difficult aspect of water-reuse planning in the City of Sterling, Colorado. And the city's proposed solution takes advantage of water rights to provide a substantial projected return-on-investment over the life of its reuse system.

New secondary treatment facilities planned for Sterling include a 4-mgd system of aerated lagoons and tertiary sand filters. Looking into possibilities for reuse of the "30/30" effluent, the city's consultants found no major legal, environmental or administrative obstacle to any of five basic system alternatives that included:

- Discharge to the South Platte River;
- Agricultural reuse with pivot sprinklers;
- Agricultural reuse by supply to existing irrigation ditch companies;
- Reuse for wildlife-habitat enhancement by the Colorado Division of Wildlife; and
- Groundwater recharge and recovery.

From a water-rights point of view, however, the problem with most of the 18 specific alternatives explored was that they represented consumptive uses. They would return substantially less water to the river than had been withdrawn. Because this would harm the interests of downstream irrigation users during the irrigation season, the city would have to purchase additional water rights, driving up the costs of these alternatives. The high costs for consumptive reuse could not be offset, the city found, by the crop revenues that would be obtained in agricultural reuse.

As a solution, the city and state have accepted a plan that will have filtered effluent discharged to the South Platte River during the irrigation season and will use the filtered effluent for groundwater recharge during the non-irrigation season (Figure 4-3). The recharge area has been sited, with the cooperation of the state, so that the normal underground return flow to the South Platte River will peak near midsummer of the year following recharge. The return flow, then, can be calculated as a water credit (additional water right) of approximately 1,000-acre-feet to the city of Sterling. The "new" water rights (that is, the right to additional water drawn upstream from the South Platte River) can either be sold, leased or used directly by the city for domestic well augmentation.

Should future water-quality standards for the river demand more stringent treatment, the city can discharge year-round to the recharge site without having to construct additional facilities.

Source: Windolph, G.R. and T.J. Carlson, Effluent Reuse in a Semi-Arid Region of the U.S. In: Proceedings of the Water Reuse Symposium, Vol. 2. AWWA Research Foundation, Denver, Colorado, 1979. pp. 1175-1189.

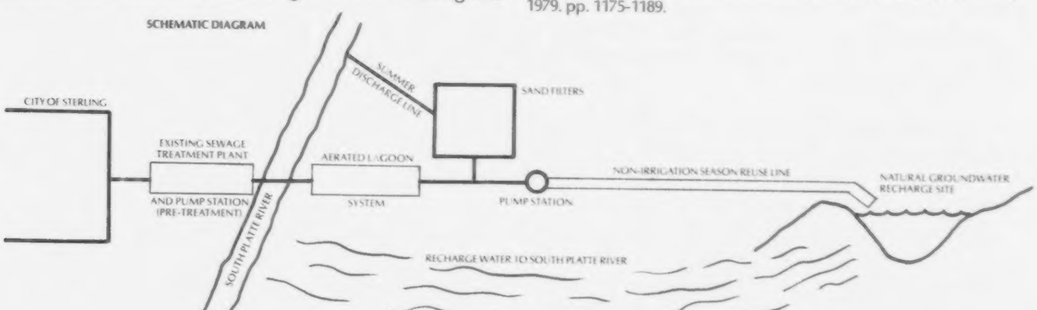
SCHEMATIC DIAGRAM
SUMMER DISCHARGE LINE
SAND FILTERS
CITY OF STERLING
EXISTING SEWAGE TREATMENT PLANT
AND PUMP STATION (PRE-TREATMENT)
AERATED LAGOON
SYSTEM
NON-IRRIGATION SEASON REUSE LINE
NATURAL GROUNDWATER RECHARGE SITE
PUMP STATION
SOUTH PLATTE RIVER
RECHARGE WATER TO SOUTH PLATTE RIVER

Figure 4-3. Schematic diagram of wastewater disposal and reuse plan recommended for City of Sterling, Colorado (figure courtesy of ARIX Corporation).

The riparian water-rights system is found primarily in the east and in the water-abundant areas. The right is based on one's proximity to water; if you border on a watercourse, you have the riparian right to the reasonable use of that water. However, as a riparian user, you cannot make any use of the water that substantially depletes the streamflow or that significantly degrades the quality of it. You can use the water only for a legal and beneficial use. The right of one riparian owner is generally correlative with the rights of the other riparian owners. Water used under a riparian right can be used only on the riparian land. Generally, the riparian rights system is judicially enforced. Thus, there are generally few procedural problems created in the statutes. Instead, for careful interpretation of riparian rights issue, look to case law decisions.

Summary of Major Water Rights Issues. The impact of the water rights issue on a program of water reuse can be profound. If it seems to be a major concern, you should consult professional legal advice. We offer the following generalizations:

- **Injury to others:** If your water-reuse program could substantially reduce flows in a local watercourse, you can expect problems associated with water rights.
- **Water sources:** Water-rights law for streams and rivers is relatively clear and well-defined, but is less so for other surface-water sources and even less so for groundwater. You should obtain proper legal advice if contemplating a program that will affect groundwater.
- **Reducing withdrawals:** A water-reuse program that reduces withdrawals from your water supply will probably pose no conflict with water-rights issues.
- **Reducing discharge:** Some uses of reclaimed water can reduce or eliminate the discharge of water to the watercourse from which freshwater is withdrawn. Examples of such uses include evaporative cooling, infiltration/percolation through irrigation, or diversion to a different stream or watershed. Multiple use of water is generally acceptable under the law, but reducing watercourse flows through reuse is usually not acceptable. Therefore, although a discharger of wastewater-treatment plant effluent is not generally bound by statute to continue the discharge, withdrawal for reuse could face legal challenge and could result in serious economic and environmental losses downstream.
- **Changes in point-of-discharge or place-of-use:** In appropriative states, the statutes might contain laws designed to protect the area of the origin of the water, to limit the places of use, or to require the same point of discharge. In riparian states, the place of use can be an issue: potential users located outside the watershed from which the water was originally drawn (or, for that matter, outside the jurisdiction abutting the watercourse) might have no claim to the water.
- **Hierarchy of use:** Presumably, with water reuse, the "reasonable-use" issue would not arise; it should be arguable that recycling water is for a good use, particularly if such recycling is economically justified. Nevertheless, a hierarchy of use still exists in both riparian and appropriative law. In times of water shortage, it is possible that a more important use could make claim to reclaimed water that, for example, is being used for industrial process water.
- **Indian water rights:** In the West, a particularly sensitive issue is that of the water rights of Indian reservations. Although there have been many decisions relating to Indian water rights, there is still a great deal of uncertainty as to how those decisions should be interpreted. If you anticipate any potential conflict with Indian water rights, you should obtain a very careful legal interpretation.

FRANCHISE LAW

A franchise is a special right or license granted to an individual or corporation to market goods or services in a particular area. Exclusive franchises are often granted when economies-of-scale do not warrant competition, such as in the right of public and private electric utilities to provide electric service to their exclusive franchise areas. The problem as it could apply to water reuse is that you might be attempting to do something that is exclusively the right of some other entity to perform. Some other water-supplying entity might have the exclusive right to sell water in its service area. A municipal wastewater-treatment agency attempting to institute reuse in an area receiving water service from a private water-supply corporation could find itself in direct conflict with the corporation's right to be the exclusive provider of water. The agency could be sued for lost revenues, or, more likely, be required to negotiate a settlement for damages.

The scope of such franchise rights, like that of water rights, varies from state to state. In each case, the potential infringement upon franchise rights should be carefully considered. From a practical standpoint, franchise rights will probably not pose a particularly difficult barrier. Cases are known in which payment for damages (lost revenues) has been necessitated under franchise rights, but none known in which franchise rights issues have killed a proposed project. Since wastewater reuse is most likely to prove economically attractive in water-short regions, it can be assumed that franchise rights issues will be resolved quite easily.

CASE LAW

The final legal issue to cover is that of case law. It warrants little more in this document other than a statement that it should be assessed carefully where potential conflicts might exist or where previous conflicts have been resolved in the courts. Most likely, your general review of the statutes should enable you to recognize if there are some especially subtle issues that might have been interpreted in the courts. If so, then a review of the appropriate case law is warranted. Doing so would be an assignment for a legal professional.

Regulatory Agencies

From your review of legal issues, you will be able to determine what organizations might be involved in water reuse and what pertinent regulations are promulgated by them. For example, a law that calls for the control of activities in all streams above a specified flow (the flow parameters that define Corps of Engineers' responsibilities for streams under Section 404 of PL 92-500) will also identify the agency that is to administer the law and how that agency is to promulgate related rules and regulations. You will be concerned primarily with agencies at the federal, state and local level responsible for regulating the natural environment, allocating water resources, and protecting the public health. The regulations promulgated by such agencies are likely to define how reclaimed water can be used (for example, the Department of Agriculture and its requirements relating to irrigation water) and to cover general water-quality issues (under the mandate of the State Department of Water Pollution Control or the State Board of Health), people contact (under the auspices of the local and state health departments), or the "media" in which this could all occur (for example, streams or navigable waters regulated by the Corps of Engineers).

The review procedures are important because they help determine how to get something done. Even though your intended use for reclaimed water might be in compliance with environmental regulations, you still might have to go through lengthy review procedures and public hearings. Some of the reviews might be initiated on the local level. For example, many states and municipalities have enacted local versions of NEPA and, thus, have required comprehensive reviews of sizable projects.

IDENTIFYING THE ORGANIZATIONS AND THEIR REGULATIONS

As early as possible in your assessment of reuse potential, you should survey and establish contact with a number of agencies that have possible involvement in water reuse. You should not be surprised, however, if you find that the role of these agencies in water reuse is not well-defined. In California, a well-structured responsibility for water reuse rests with the Office of Water Recycling (OWR) in the State Water Resources Control Board. OWR's purpose is to promote the reclamation and recycling of wastewater in California; it is responsible for statewide coordination of reclamation activities and is working with other state and local agencies to resolve problems preventing the increased use of reclaimed water. Few other states have specified responsibility for reuse.

The intent of the survey is to identify as soon as possible the appropriate administering agency and regulations relating to:

- Public health;
- Water quality standards;
- State reclamation policy and/or reclamation requirements;
- Water ownership issues;
- Potential funding sources; and
- Permit requirements and review procedures.

In general, your state's water pollution control agency or equivalent thereof will have the best information on which of the above agencies are responsible for reuse issues in your state. A general list of agencies and their respective interests is presented below:

Local:

- Regional Water Quality Control Board—for effluent-quality standards, permitting requirements and procedures, regulatory review procedures;
- Department of Public Health—for effluent-quality standards, restrictions on reuse applications;
- Regional River Basin Commission, Water Management District, Water Compact Board, and/or Irrigation District—for guidelines on water-ownership issues, restrictions on reuse applications, clarification as to the jurisdiction of such agencies over water as well as the media in which the water is found; and
- A-95 Review Agency—for review requirements (federal Office of Management and Budget Circular A-95 requires that a regional agency, acting as a designated "clearinghouse," review proposed projects of regional impact if federal financial support is involved).

In many states, there are no local water-quality control boards or local agencies that administer water rights and allocations; in such cases, the municipality should refer its inquiry to the state agency level for information. In addition, if no federal funds are involved, A-95 review can be avoided altogether.

State:

- State Water Quality Control Board—for effluent quality standards, permitting requirements and procedures, regulatory review procedures;
- State Department of Public Health—for effluent-quality standards, restrictions on reuse applications;
- State Water Resource Departments, Water Compact Board—for guidelines on water-ownership issues, restrictions on reuse applications; clarification as to the jurisdiction of such agencies; and
- State EPAs—for review requirements and procedures in compliance with state-level environmental policy acts (comparable to the National Environmental Protection Act (NEPA)).

While the title of the agency may change from state to state, the purpose is the same. The state water-quality control agency has the primary responsibility for controlling and protecting the quality of waters in the state and usually for administering water rights.

Many states have not established regulations for wastewater reclamation and reuse. In a 1978 survey of State Health Departments conducted as part of a National Science Foundation study, only seven of 37 states responding were found to have some form of regulations involving the use of reclaimed water, primarily related to irrigation uses.[9] These states were California, Colorado, Kansas, Louisiana, Maryland, Pennsylvania and Utah. Since that survey, several other states have issued regulations or are developing guidelines.

Obviously, requesting information from a state water-quality control agency might not generate information on regulations governing water reuse (although it is still the best place to start). A municipality should then pursue the request with any agencies comparable to, or with responsibilities similar to, those agencies itemized here. In some states, a multi-agency hierarchy is likely to be found; in other states, such as those in the Northeast, there may be very little direct reference to water-reuse issues. Thus, it will be incumbent upon the municipality to assemble its own understanding of "State Water Reuse Procedures," likely to consist of water-quality effluent standards, health codes and regulations, and environmental impact review procedures.

If you consider your proposed project a viable one, but find yourself constrained by the lack of regulatory guidelines, you should be prepared to take an advocacy position on reclamation and reuse standards, to "educate" the appropriate regulatory agencies as to regulations and standards promulgated in other states, and to encourage the regulatory agencies to accept the standards with which you intend to comply. The city of St. Petersburg, Florida, faced with a lack of state water-quality guidelines for use of reclaimed water, set its own standards, based primarily on what quality it knew it could assure. In addition, in the absence of any monitoring requirements, the city established, and had accepted by the State Department of Environmental Regulation, a groundwater-monitoring program.

You should also note that some states are beginning to take the advocacy position by requiring that reuse be considered in new water-source development as a criterion to state grant assistance. Proposed legislation in California will call upon the State Water Resources Control Board, in its review of new or altered water-rights requests, to require that reuse be employed to the greatest possible extent. Related to this is the case of the Castroville Project sponsored by the Monterey Peninsula Water Pollution Control Agency, which is utilizing reclaimed water for irrigation purposes. The project was developed because the State Water Resources Control Board objected to an application for a federal small project loan on the grounds that reclaimed water had not been considered as a source of water.[10]

Finally, one regulatory problem which you will probably confront is that of the eventual discharge of the reclaimed water if it is discharged as a point source. It is likely that the reusers will have to acquire discharge permits and will have to provide significant treatment to the water. As reported in *Demonstrated Technology and Research Needs*, industries have resorted to evaporation or deep-well injection for disposal or have simply proved to the water-quality agencies that the total amount of pollutants discharged is less than what would have been contained in treatment-plant effluent.[11]

Federal:

- Environmental Protection Agency (EPA)—for effluent quality standards, assistance in conjunction with developing wastewater treatment facilities;
- Water and Power Resources Service—for guidelines on potential reuse applications;
- Department of Agriculture—for restrictions as to the quality of effluent that can be applied to arable land; and
- U.S. Army Corps of Engineers—for permitting requirements should the reuse application affect navigable waters (via withdrawing from or discharging to such waters) and wetlands.

As with some state agencies, the federal government is beginning to assume an advocacy role in water reuse. EPA is now requiring that water conservation and reuse be considered in wastewater facility planning as a prerequisite to federal funding. Congress had mandated EPA to encourage water reuse by enacting provisions offering financial incentives for reuse and requiring that reuse be considered as part of facility planning.[12]

THE REVIEW PROCEDURES

A variety of formal reviews is required in order to implement some programs of water reuse—for the initiation of a capital project, for the approval of a bond issue, for review of an environmental impact assessment, etc. These review procedures, if lengthy, can delay implementation of your project. By identifying them as early as possible, you can incorporate them realistically into your overall schedule.

As you contact different agencies responsible for regulating water reuse, ask their representatives to describe their review and procedural requirements. Involve such agencies in your planning from an early stage, as their familiarity with your proposed program will work to its advantage. Of particular interest should be the environmental and funding review periods and procedures, and public hearing requirements.

If there should develop any organized opposition to your reuse project, your project will be most vulnerable in the area of noncompliance with administrative and statutory requirements. Early review of applicable law, initial contacts with responsible agencies, and knowledge of the review procedures to follow will strengthen your plan's chances for implementation.

Guidelines for Implementation

Based on your preliminary understanding of the legal and institutional issues, you can take specific steps in your reuse planning to address these issues.

Maintain Contact with the Agencies. Throughout development of the reuse project, you should continually monitor the reactions of the federal, state and local agencies involved. The intent is to maintain such agencies' understanding of what you have in mind, and to keep them informed of what you expect from them, particularly if that includes certain permit reviews or the enactment of new legislation.

Regulatory agencies are generally unable to provide any solid endorsement of a program before its actual proposal or permit application is submitted. In advance of your submittal, however, you should try to know what their anticipated reaction will be. You must continually acquire their tacit approval of your program, so that regulatory review does not become a critical stumbling block in the implementation stage of the project.

Develop a Realistic Schedule. By developing a comprehensive implementation schedule, you can anticipate any lengthy review procedures, the time needed to enact any required legislation, and the timing of any public hearings that must be held. It is especially important to identify any permit review procedures and whether they are able to occur concurrently or must occur consecutively, and in what order.

Assess Cash Flow Needs. Develop an accurate assessment of your cash flow needs so that you can anticipate your funding requirements, formulate contract provisions, and devise cost-recovery techniques, as you develop a more complete understanding of what your reuse program will entail.

Consider Institutional Structures. Consider in detail the alternative institutional structures under which you could purvey reclaimed water. You should carefully examine the advantages and disadvantages of each, particularly as relating to the financial aspects of the reuse project. You should identify as early as possible any legislative changes that might be required to allow you to create the necessary institutions, and the level of government at which the legislation must be enacted. And, when appropriate, you should move to establish the institutional structure under which you wish to operate, if any change is required.

CASE STUDY:

Industrial Reuse: Who Should Own and Operate the Facilities?

Three current examples of industrial use of reclaimed water illustrate some forms of ownership/operation that can be structured into a reuse plan.

Municipal Ownership/Operation. Colorado Springs, Colorado, has reclaimed a portion of its wastewater since 1960. The application is unique in that the city operates two separate AWT facilities to serve different reuse needs. Both facilities are located at the city's secondary wastewater-treatment facility, which employs trickling filters. One AWT process train consists of dual-media filtration, chlorination and storage of the secondary effluent. Reclaimed water from this train is piped through a distribution system to irrigate city parks, a golf course, a cemetery, an industrial area, and grounds of the Colorado College. The second AWT process train consists of lime coagulation and settling, recarbonation, dual-media pressure filtration, activated-carbon adsorption, chlorination and storage. This water is piped two miles to the municipal power plant for use as cooling-tower make-up water.

User Ownership/Operation. Reclaimed water from the Clark County, Nevada wastewater-treatment facility, located in Las Vegas, is utilized for both irrigation and cooling-tower make-up water. At this installation, unlike Colorado Springs, the user accepts secondary effluent and is responsible for pumping it from the Clark County facility. Part of this water is subsequently used to irrigate two golf courses and agricultural acreage. Water is also pumped to two Nevada Power Company facilities, each of which provides lime treatment, chlorination and storage, prior to use at each of two power-generating stations.

Joint Ownership/Operation. In some cases, the AWT processes may be split between effluent supplier and user. In Contra Costa County, California, the Central Contra Costa Sanitary District (CCCSD) is responsible for much of the wastewater-treatment and -disposal function in the country's industrial areas. Most of the major oil and chemical companies in the area purchase water from the Contra Costa County Water District (CCCWD). In 1972, the Sanitary and Water Districts signed a contract providing for sale of the Sanitary District's effluent to the Water District for further treatment and resale to six industrial users. The Sanitary District provides secondary treatment and filtration of 15 to 30 mgd, with delivery to a clearwell operated by the Water District. The Water District is operating an ion-exchange softening facility and a storage and distribution system to supply industries with 15 mgd for cooling tower users. The project is designed to meet an ultimate 30-mgd demand for various industrial uses. Industries currently served include the Shell and Lion Oil Companies, Stauffer and Monsanto Chemical Companies, and two Pacific Gas and Electric Company installations.

Prepare Application Documents. At some point, you will prepare the final documents required to support your intended project: funding applications, permit and review procedure applications, bond prospectus, letters of intent, etc. You should carefully anticipate the time requirements of such reviews. For example, even in especially successful cases, such as Contra Costa, it required several years to overcome the institutional hurdles involved.

Prepare Legal Contracts. Finally, you must prepare your draft contracts. In doing so, there is a variety of issues that should be dealt with. Provisions relating to quality and quantity are obviously essential. You must also specify the range in which each can fluctuate, and the remedies, should the quantity or quality go outside that range. Some statement should be made if one party is required to provide storage facilities or if the reuser may occasionally have to look to alternative sources of water. There must be an explicit statement as to how the reuser will pay for the recycled water, and to what extent, and for what reasons he is responsible and liable for costs. Both parties must be protected explicitly in case either party defaults, either by bankruptcy or by the inability to comply with the commitments of the agreement. The monitoring responsibility must be specified, especially if the recycled water is being utilized for irrigation purposes and a monitoring program is required.

The discharge-permit responsibility must also be specified. If the recycled water is being used for once-through cooling purposes (and, in some cases, for blowdown), the discharge of that cooling water will require a NPDES permit. The responsibility of acquisition and compliance with the NPDES permit must be explicit.

General compliance with environmental regulations must be assigned to each party. For example, if the crops grown are not to be utilized for human consumption, it is appropriate to assign the responsibility of compliance with such regulation to the reuser.

Finally, the ownership and maintenance of the facilities must be stated, particularly for the transmission and distribution facilities of the recycled water. The point at which the water conveyance facilities become the property and responsibility of the reuser must be explicitly stated. In the case where the reuser is a private enterprise, that statement should be reasonably straightforward. However, in the case where the reuser is another municipal entity, it is especially important that each party know its responsibility in the operations and maintenance of the facilities.

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Financing a Reuse Program

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Using the preliminary economic analyses discussed in Chapter 3, you can weigh the relative merits of various reclamation and reuse alternatives, comparing the alternatives to each other and to the status quo—the continued exclusive dependence on freshwater for all water needs. Based on this preliminary comparison and the more detailed cost/benefit study that should follow as you move toward implementation, you might be able to identify a reuse alternative(s) that could generate a number of economic benefits for your community. The purpose of the financial analyses discussed in this chapter is to determine how the community can best raise money to pay for all costs of construction, operations-and-maintenance (O&M), and debt service on the selected project.

The significance of the financing problem is well-defined in *Interim Guidelines* prepared for the Office of Water Recycling, California State Water Resources Control Board:[1]

> "...A project which generates a great many net benefits to society may not ultimately be chosen because sufficient capital is unavailable to construct and operate the project or may cause financial hardship on other agencies, such as fresh-water purveyors...Financial feasibility analysis compares the monetary costs of building and operating the project with the funds generated from user fees, standby fees, and funds from loans, bonds, government grants, and contributions from developers and new applicants for service."

In other words, although you may have identified some net economic benefits that contribute to the attractiveness of the proposed reuse project before it is actually built, you still must raise capital to fund the construction activities and must generate a stream of revenues to pay the operations-and-maintenance costs and the debt-service costs of the project. Moreover, and of equal importance, you must work with prospective users to determine how their costs for tying into and using the nonpotable supply systems should be financed.

In this section, five sources of funds are discussed: the operating budget or the cash reserves of the developer of the reuse facility, a tax levy or an increase in existing use charges, federal and state grant programs, municipal bond issues, and new use charges for the reclaimed water.

Different reuse planners have approached the basic funding issue in different ways. In Contra Costa County in California, both the water and the sanitary districts (the dual agencies that were pursuing a reuse project) recognized that the project could not proceed if the sanitary district did not receive state and federal grants for funding of the project. The difficulties were overcome, and Contra Costa has become one of the most widely recognized reuse projects in the country.[2] In Mission Viejo, California, on the other hand, the planned reuse project was funded entirely with local funds. The Santa Margarita Water District serving Mission Viejo required in very expeditious order the services of a new wastewater-treatment facility and the supply of reclaimed water for irrigation purposes to supplement its existing water supply. Thus, since the project was economically justified, the facility was built and funded by $22 million raised through the sale of general obligation bonds and by an $8 million contribution from a large local developer.

How to Begin

The most important prerequisite to determine how to fund the reuse facility is to develop an accurate statement of cash needs: for planning, design, and construction activities, as well as for the operations-and-maintenance and debt-service costs. In addition to anticipating these costs, you should project the stream of revenues that will be produced by the particular project, either estimated on the basis of a charge that is a certain percentage of the present charge for potable water, or on the basis of contractual commitments made in advance of completion of the plant, or on the basis of the use charge that is expected to be imposed.

It is necessary to know the funding options that are available, and to relate the particular activities of implementing a reuse program to the most practical means of funding each activity. For example:

- **Operating budget.** Practically all activities associated with the development of the reuse facilities could be funded out of an existing wastewater-treatment-plant operating budget. (In some instances, a water-supply agency seeking to expand its water resources would find it appropriate to apply a portion of its operating funds in a similar way.) To do so would simply require that funds be set aside for those purposes. In addition, any reserve accounts could be utilized, if available.
- **Tax levy or user charges.** Similarly, practically all activities could be funded through an *ad valorem* tax levy, or through an increase in the present user charge.
- **Grants programs.** Capital needs could be obtained largely through federal and state grant programs to fund reuse projects, particularly those programs designed specifically to support reuse.
- **Bond issues.** The local share or (should the project not be grant eligible) the total cost of construction activities in the reuse project could come from the sale of bonds.
- **Use charges.** Operations-and-maintenance (O&M) and debt-service costs could be recovered by imposing a use charge upon the users of the reclaimed water.

These five sources of funds will be discussed in greater detail in the following sections.

Operating Budget and Cash Reserves

For funding of reuse planning and design functions, and moderate capital improvements, you might first look to the operating budget or to any reserve amounts of cash. It is quite legitimate to utilize the operating budget for planning activities or business costs associated with assessing the reuse opportunity. Furthermore, if cash reserves are accruing for unspecified future capital projects, then you could utilize those funds (or if you anticipate implementing a reuse project in the future, you could begin now to set aside a portion of your operating revenues in a cash reserve). The obvious advantage of using this type of source of cash is that the utility board or ruling body of the wastewater treatment utility can act on its own initiative to allocate the necessary resources—there is no need to raise taxes or water and/or sewer rates; the resources can be tapped at the utility's prerogative.

These sources are especially practical when you anticipate only very limited expenditures to implement the reuse program, or when the reuse project will provide a general benefit to the entire community (as represented by the present customers of the utility). In addition, utilizing such resources is practical when your reuse project will distribute reclaimed water at little or no cost to the users, and therefore will generate no future stream of revenues to repay the cost of the project.

Property Taxes, Special Assessments, and Existing User Charges

If the resources available in the operating budget or the cash reserves are not sufficient to cover the necessary system activities and facilities, then the next source of funds to look to is revenues generated by increasing existing levies or charges. If you are funding activities now with property taxes or special assessments, you could increase those levies and designate the revenues for expenses associated with the reuse project. Similarly, you could increase the use charge presently paid for water and sewer services. As with the use of the operating budget or cash reserves, the use of property taxes, special assessments or use charges is legitimate if the expenditures for the project are not anticipated to be sizable or if a general benefit accrues to the entire community (or special assessment district).

Property taxes and special assessments are intended to tax proportionately all the residents within a municipality or special district for the use of a municipal service; the charges either are based upon assessed valuation of property or are a flat fee of some sort. Property value is an appropriate means of allocating the costs of the improvements of service if there is a "general good" accruing to all members of the community. It is also a useful means of allocating the cost of debt service for a project in which there is general good to the community and in which the specific O&M costs are allocated to the direct beneficiaries. The *ad valorem* or special assessment allocation of the costs would be appropriate for such reuse applications as:

- Irrigation of municipal landscaping;
- Municipal recreational impoundments;
- Fire-fighting water;
- Water for flushing sewers;
- Groundwater recharge for saltwater intrusion barrier; and
- Parks and other uses.

All such projects have benefits that accrue to the residents of the municipality in general, or to those who can be isolated in an identifiable special district. Thus, a simple cost-allocation technique suffices.

Similar use can be made with resources generated by increasing any existing use charges. However, to do so legitimately, benefits of the proposed project should primarily accrue to those presently utilizing the services of the water or wastewater utility. This would be the case, for example, when water reuse precludes the need to develop costly advanced-wastewater-treatment facilities or a new water-supply source. As cited elsewhere in this manual, these are among the reasons why many municipalities first consider water reuse.

Federal and State Grant Programs

When the capital expenditures associated with a reuse project are anticipated to be extensive, then you may have to look to the typical means of raising capital—acquiring grants and assuming debt by selling bonds. Grants are discussed in this section, and bond issues are reviewed in the following sections.

As reuse is currently practiced, only infrequently are substantial capital improvements made to the municipal wastewater-treatment plant for the purpose of supporting water reuse. Typically, the reuser accepts the effluent as it is discharged from the treatment plant. As interest in reuse expands, however, so can the need for significant amounts of capital funds, both to cover treatment-process improvements to produce higher quality effluents for high-level uses, and to cover costs of conveying reclaimed water to new users.

Grant programs can provide the resources required to fund programs of practically any magnitude, provided that they meet grant-eligibility requirements. Some funding agencies are taking an increasingly active role in facilitating wastewater-reuse projects. In addition, many funding agencies are receiving a clear legislative and executive mandate to encourage water reuse.

To be successful over the long term, any reuse program must be able to "pay for itself." It is true that federal- and state-supported subsidies can underwrite substantial portions of the capital improvements necessary in a reuse project—and grant funds can also help a program to establish itself in early years of operation. But you should not count on these aid funds in preparing financial arrangements for a project unless their availability is assured. Some aid programs require that funds be appropriated each year by Congress or the state legislature, and, in many instances, the amounts appropriated are far less than those needed to assist all eligible projects. For the same reason, once your project is underway, you should strive to achieve program self-sufficiency as quickly as possible—meeting O&M costs and debt service on your local share of capital costs by generating an adequate stream of revenues through local budget set-asides, tax levies, special assessments and use charges, as discussed above.

The prime source of grants for funding of reuse projects is the federal government. Information on specific source possibilities can be found in the *Catalog of Federal and Domestic Assistance*, prepared by the federal Office of Management and Budget and available in federal depository libraries. It is the most comprehensive compilation of the types and sources of funding available.

A number of particular sources of funds should be explored:

EPA SOURCES

The language of the Clean Water Act of 1977, PL 95-217, supports water-reuse projects through the following provisions:

- Section 105j of PL 92-500 of 1972 provides grant assistance for research and development projects in innovative treatment technology (AWT/recycling). It was amended to include provision for grants of up to 100 percent for the costs of performance evaluations, staff training, and the preparation of technical operation guides.
- Section 201 of PL 92-500 was amended to ensure that municipalities are eligible for "201" funding only if they have "fully studied and evaluated" techniques for "reclaiming and reuse of water."
- A new Section 214 was added; it stipulates that the EPA administrator "shall develop and operate a continuing program of public information and education on recycling and reuse of wastewater..."
- Section 313, which describes pollution control activities at federal facilities, was amended to ensure that WWTPs will utilize "recycle and reuse techniques" if estimated life-cycle costs for such techniques are within 15 percent of "the most cost-effective alternative."

At this writing, EPA had not yet fully formulated its funding policy based on these provisions of the Clean Water Act (see Preface). It appears, however, that EPA will not afford substantial federal construction grant funding beyond that available for the least-cost pollution-control alternative. Ancillary facilities for reuse—conveyance systems for reclaimed water, monitoring devices, distribution storage tanks and the like—might not be eligible for funding unless the primary purpose of the whole, since project inception, has been achievement of water-pollution-control objectives.

Even if a reuse project qualifies for EPA funding beyond the usual 75 percent federal share, there can be pitfalls. Funds granted for wastewater-treatment capital improvements are contingent on implementation of an industrial cost recovery (ICR) system. This would tend to work against industries' acceptance of an industrial water-reuse plan, since the cost advantages of the reclaimed water would be offset by the higher wastewater-disposal charges caused by ICR. One way to avoid this situation is to have the sanitation agency assume responsibility for wastewater treatment, and establish a separate agency for additional treatment and distribution of reclaimed water. The new agency can then impose a use charge upon the purchasers of the reclaimed water that would cover the costs of the reclamation facility, and those purchasers would not be subject to an ICR system.[3]

OTHER FEDERAL SOURCES

There are at least four other sources of federal support. First, there is the Farmers Home Administration (FmHA) of the U.S. Department of Agriculture (USDA). Under the FmHA programs, grants and loans are available to public agencies and non-profit corporations which serve areas with populations under 10,000. The amount of the grant or loan is restricted by that amount necessary to lower the user costs to a reasonable rate, based on the median family income of the community. In addition, the sum of the FmHA grant and other state and federal grants cannot exceed 50 percent of the project costs. Thus, projects funded by Clean Water grants will not be eligible under FmHA programs.

Second, the Water and Power Resources Service (formerly Bureau of Reclamation) of the U.S. Department of the Interior provides loans for non-federal design and construction of irrigation distribution and drainage systems on federally-authorized land-reclamation projects. Funds are not available for wastewater-treatment facilities. The Ventura County, California reclamation project, for example, is being partially funded by Service support. In addition, the water-reclamation project in Gilroy, California was mostly financed by a loan from BUREC.[4] The reclamation facility provides water suitable for irrigation of agriculture and landscaping; however, BUREC's prime interest in the project was that a supplemental water supply to the declining groundwater levels could be developed.[5] Finally, the Service, in cooperation with the City of Fairfield and the Solano Irrigation District, California, is currently investigating the use of reclaimed water to protect and maintain the Suisun Marsh in Solano County. The reclaimed water is intended to be used for the management of wildlife habitat and for agriculture irrigation.[6]

Third, U.S. Small Business Administration (SBA) will provide low-interest loans to small businesses for wastewater-control equipment required by regulatory agencies. The funds can be used for pretreatment of industrial waste to reduce toxic and saline constituents in reclaimed water. To obtain a loan from the SBA, the EPA must be able to certify that the project is required to comply with either federal or state water-pollution-control requirements and that other funds are not available.

Finally, the Office of Water Research and Technology of the Department of the Interior will provide research-and-development funds for water reclamation projects, particularly for demonstration projects, that meet OWRT-identified priority needs

STATE SUPPORT

State support is generally available for wastewater-treatment facilities, wastewater-reclamation facilities and conveyance facilities, and, under certain conditions, for on-site distribution systems. Obviously, a prime source of funding is the state support that usually accompanies Clean Water grants. State support often equals one-half of the federally-unfunded but eligible costs of the project. However, the formula varies from state to state.

You should determine what other types of state assistance are available as a by-product of state programs to encourage water recycling and resource conservation in general. As discussed in Chapter 4 of these *Guidelines*, as you contact state agencies to determine what their roles might be in the institutional issues involved, you should request any available information relating to state assistance.

CASE STUDY:
Financing for Irrigation in Gilroy

Many of the projects described in these *Guidelines* have been funded in part by "Section 201" grants from PL 92-500, as administered by the EPA. Other communities have looked to other sources of funding, ranging from locally-raised funds to grants from other federal agencies. The Santa Clara Valley Water District in California, for example, obtained a $1.25-million loan from the Water and Power Resources Service (formerly the U.S. Bureau of Reclamation, or BUREC) to help finance its $1.8-million reuse project; the District will repay the loan and meet other costs through sale of reclaimed water and through contributions from the City of Gilroy and another water district. The BUREC loan was provided for under the Emergency Drought Relief Act of 1977.

The Gilroy project, in operation since 1977, involves the reclamation of domestic wastewater for landscape and agricultural irrigation. The City's reclamation facility treats primary effluent from an existing WWTP, providing additional oxidation in a 15-acre oxidation pond with floating aerators, mechanical strainers, and chlorination facilities. The reclaimed water is then pumped through an eight-mile pipeline to an existing terminal reservoir with a capacity of 120 acre-feet. Chlorine residual is automatically monitored two miles along the 12-inch distribution main to ensure adequate disinfection; too low a residual will trigger automatic shutdown of the system.

The initial market for the reclaimed water was to include about 300 acres of agricultural irrigation, comprising primarily nursery crops, flowers and seed crops, and landscape irrigation for a municipal golf course, city parks and school grounds. Amendment of the State's Title 22 code by the Department of Health Services eliminated the parks' and school grounds' irrigation, however, as the amendment requires a higher coliform standard for this type of reuse than had been provided for in the Gilroy project.

The location of the reclamation facilitiy, distribution system and users are indicated in the accompanying figure. The project effectively supplements the Santa Clara Valley Water District's groundwater supply by reducing irrigation demand and leaving the groundwater available for potable purposes.

All markets are required to pay for a specified minimum quantity of water, based on individual contracts, whether or not the water is used. Contracts with individual users price the reclaimed water $10 per acre-foot for agricultural purposes, while the city pays $40 an acre-foot for reclaimed water used in irrigating municipal grounds.

Source: Fowler, L.C. Water Reuse for Irrigation—Gilroy, California. In: Proceedings of the Water Reuse Symposium, Vol 2. AWWA Research Foundation. Denver, Colorado, 1979. pp. 2060-2067.

In your pursuit of state assistance, you should request from your state grant-administering agency a copy of the criteria utilized to develop priority lists for state assistance. You should use your understanding of those criteria to accentuate any facets of your proposed reclamation project that would improve your position on the priority lists.

CONTACTING FUNDING AGENCIES

It is necessary to contact potential funding agencies in order to acquire a preliminary commitment for the funds required. With reference to federal and state programs, it can be assumed that the application procedures are explicitly laid out within each agency; thus, you should contact the respective agency to get information relating to grant acquisition and award criteria. Presumably, most of the criteria will be based on technical and economic feasibility, and on your response to any federal or state incentives to encourage water reuse.

Municipal Bond Issues

The other source of capital for a municipality is to assume debt—that is, to borrow money by selling municipal bonds. With almost any water-reclamation project, some local support will be required to finance the project, and most likely, this money will have to be raised through a bond issue (or as one portion of a bond issue). In reviewing enabling legislation, you should determine to what extent and under what restrictions you can assume debt obligations and, in fact, should determine which financial instruments offer the greatest advantage. Among the types of bonds commonly used for financing public-works projects are:

- **general obligation** bonds, paid back through general property taxes or service-charge revenues;
- **special assessment bonds,** payable only from the receipts of special benefit assessments (and carrying a higher interest rate than general obligation bonds);
- **revenue bonds,** paid back through service charges—and useful in regional or sub-regional projects because revenues can be collected from outside the geographical limits of the borrower; and
- **short-term notes,** usually repaid through general obligation or revenue bonds.

A municipal finance director or bond advisor can describe how you will be expected to justify the technical and economic feasibility. You must be able to show potential investors how you will generate the cash flow to cover the costs of the reuse project. Thus, you must be prepared to substantiate your projections of the required capital outlay, of the anticipated operations-and-maintenance costs, of the revenue-generating activities (that is, your user-charge system, etc.) and of the "coverage" you anticipate—that is, the extent to which anticipated revenues will more than cover the anticipated capital and operations-and-maintenance costs.

User Charges

Finally, you may choose to impose a use charge on those receiving the reclaimed water. That charge would be utilized to generate a stream of revenues with which to defray the operations-and-maintenance costs of the reuse facility and the debt service of any bonds issued.

With most present reuse applications, user charges are flat fees that bear little resemblance to the actual cost of delivering the water. Historically, effluent has been thought of as something to be disposed of, not as a product to be sold. Consequently, the fees attached to reclaimed water have not generally reflected what realistic user charges would be. More recent programs of water reuse, however, are shifting toward metered charges.

In one EPA study, it was found that most industrial users are paying for the reclaimed water on a volume basis and that most irrigation reusers are receiving the reclaimed water free or at a minimal charge.[7] In many cases in which there is a charge for reclaimed water sold for irrigation, a flat fee is negotiated annually.

In a user-charge system, the intent is, as before, to allocate the cost of providing reuse services to the recipient. With a user-charge system, it is implicit both that there is a select and identifiable group of beneficiaries to which the costs of treatment and distribution can be allocated, and that the public in general is not the beneficiary.

The principles of establishing rates for use of reclaimed water follow closely those used in establishing rates for potable-water systems. Several points of interest relating specifically to the calculation of a user charge for reclaimed water are offered below. First, it can be assumed that the user charge should be less than the cost of freshwater available from the existing municipal or private water-supply system (Figure 5-1). If it were not, then, generally, the potential user would not be interested (except in an exceptionally water-poor area where, under an appropriative-rights system, a low-priority user would be willing to pay a premium for reclaimed water in order to have an assured source of water). Irvine Ranch Water District, for example, arbitrarily chose a user charge amounting to 50 percent of the potable-water costs. Second, the user charge becomes complicated if there are several reusers that require different qualities of water. And third, the calculation is further complicated in the process of determining which costs should be allocated to the wastewater-treatment user charge and which to the water-reuse user charge. The following comments help clarify these issues.

CASE STUDY:
Two Examples of User Charges

One type of "user charge" is no charge at all. Particularly in irrigation reuse systems, this practice has been the norm. For example, in Santa Rosa, California, reclaimed water used for irrigation purposes is delivered free of charge on the condition that a stipulated volume will be used each year. The justification for this type of arrangement is that the wastewater-treatment authority finds it more cost-effective to make effluent available for irrigation than to absorb additional costs for meeting stringent discharge standards. Probably, as more purveyors of reclaimed water recognize the intrinsic value of their product, they will begin to charge a realistic fee for the water, although this will vary according to the cost-benefits perceived in each case.

A dual costing system was originally proposed for industrial water-reusers in Contra Costa County. The Water and Sanitary Districts agreed on a charge of $3.50 per acre-foot for the first block of reclaimed water used, up to about 19,000 acre-feet per year. Once this minimum quantity had been purchased by the Water District each year—enabling the Sanitary District to meet its debt-service obligations on the local share of construction costs for the reclamation facilities—then the price would be reduced to $0.75 per acre-foot for the rest of the year, covering operation-and-maintenance expenses. This dual-charge system has since been modified somewhat; current agreements call for a flat price of $4 per acre-foot, with a stipulated minimum amount to be purchased each year by the Water District. Retail costs to the industrial users have not yet been established, although potable-water costs to these users are about $35 per acre-foot. The $4 charge is expected to cover the Sanitary District's share of costs for the reclamation facilities. Because the Water District's distribution-system costs cannot be recovered in reclaimed-water fees to users without greatly exceeding potable-water costs of $35 per acre-foot, the unrecovered amount will be apportioned among all Water District customers, in recognition of a general good being obtained through reuse.

Sources: Riha, B.J. Wastewater Irrigation—The Price Is Right. The American City & County, March 1976. pp. 55-57.

Weddle, C.L., D.G. Niles and D.B. Flett. The Central Contra Costa County Water Reclamation Project. In: Complete Water Reuse—Industry's Opportunity. L. K. Cecil, ed. National Conference on Complete Water Reuse, sponsored by The American Institute of Chemical Engineers, 1973. pp. 644-654.

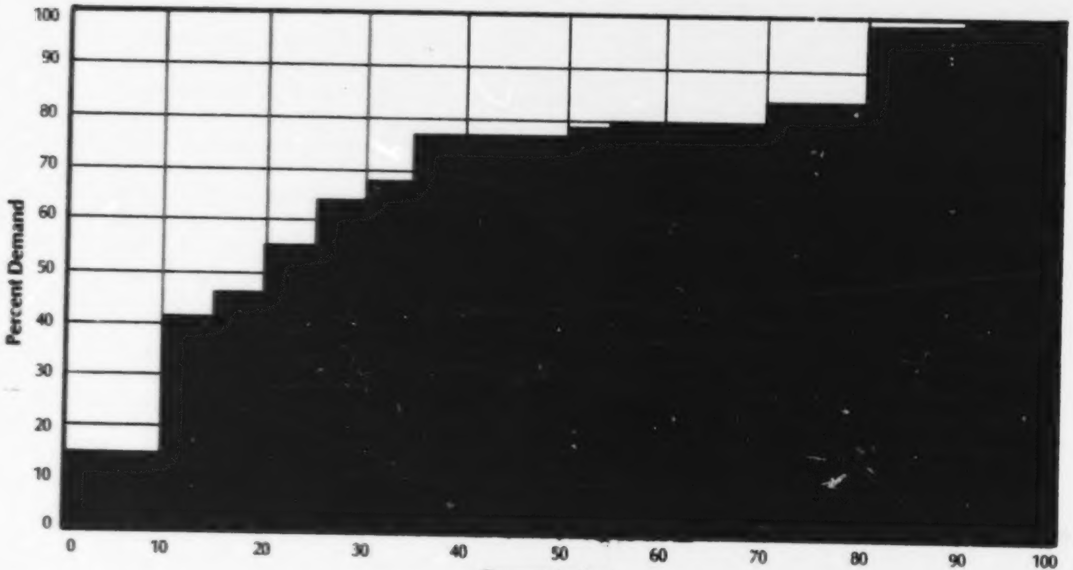


Figure 5-1. Demand for reclaimed water increases with increased savings over potable water rate. (Source: Grant, F.A., G.P. Treweek and W. Horne. Water Reuse and Recycling: Industrial Cost Analysis and Pricing Strategies. Consulting Engineer, Vol. 53, No. 3, September 1979. pp. 118-124.)

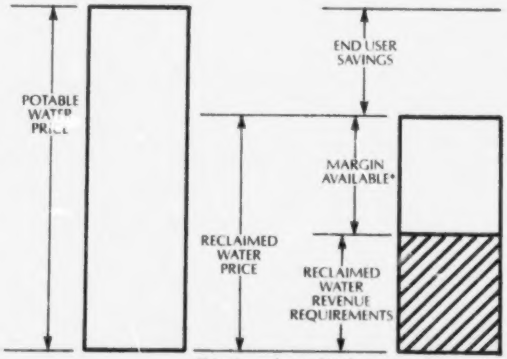
There are two prime means of allocating costs that are to be incorporated into a user charge; the **proportionate-share basis** and the **incremental-cost basis.** Under the commonly used proportionate-share basis, the total costs of the facilities are shared by the parties in proportion to the benefit that each derives from the facilities. In apportioning the costs, you should consider the quantity and quality of the water, the reserve capacity that must be maintained, and the use of any joint facilities, particularly means of conveyance. When there are a large number of parties using reclaimed water, classes of users can be identified, with a set charge assigned to each class based on the general characteristics of the service to that class. For most new or developing water-reuse applications, this is not likely to be required; initially, at least, probably only a few parties will be involved.

The incremental-cost basis allocates to the marginal user only the marginal costs of providing service. This system can be used if the community feels that the marginal user of recycled water is performing a social good by conserving potable water, and so should be allocated only the additional increment of cost of the service. However, two points should be noted. First, if the total cost savings realized by reuse are being enjoyed only by the marginal user, then in effect the rest of the community is subsidizing the service; does the community really wish to do so? Second, economies-of-scale might be realized in the overall system due to the marginal user's joining the system; other users may feel that they should enjoy part of the savings resulting from these economies (Figure 5-2).

For water-reuse systems, the proportionate share basis of allocation is most appropriate. The allocation should not be especially difficult, because you will probably have only one or two reusers at first, and the facilities required to support their needs should be readily identifiable. The best rule of thumb is to allocate to wastewater charges the costs of all treatment required for compliance with NPDES permits; all additional costs, the costs of reclamation and conveyance of reclaimed water, should be allocated to the water-reuse user charge. General administrative costs could also be allocated proportionately or, in this case, via the incremental cost basis: all wastewater administration would be charged to the sewer-use charge, and all additional administration to the water-reuse user charge. In some cases a lesser degree of wastewater treatment will be required as a result of water reuse. The effect may be to reduce the wastewater user charge. In this case, depending on local circumstances, the savings could be allocated to either or both the wastewater discharger and the water reuser.

With more than one water reuser, you might have to produce different qualities of water. If so, the user charge becomes somewhat more complicated to calculate, but it is really no different than calculating the charges for treating different qualities of wastewater for discharge. If, for example, you are distributing water to two different irrigation needs, one requiring better water than the other, then presumably you can base the calculation in relation to the cost of treatment to reach the quality provided.

Of course, if your two users are one farm and one industry, then the measure of quality might be entirely different—for example, in terms of BOD and the absence of corrosives, respectively. Even in this case, however, you should be able to identify the facilities required to reclaim water to the required quality for each.



*Margin can be used for future expansion, and/or to offset loss in fixed revenue of potable system

Figure 5-2. Illustration of a reclaimed-water pricing policy concept. A margin or profit exists when costs are less than revenues generated by selling the reclaimed water; this margin can be used to lower wastewater discharger charges, to lower water prices for all water customers, to assist in financing other environmental improvement programs, or to pay off portions of existing water systems when these systems have been abandoned due to use of reclaimed water. (Source: Ernst & Ernst. Interim Guidelines for Economic and Financial Analyses of Water Reclamation Projects. Prepared for Office of Water Recycling, State of California Water Resources Control Board, Sacramento, California, February 1979. 83 pp.)

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Public Involvement in Reuse Planning

6

As we have tried to show in these *Guidelines,* development of a workable water-reuse program grows out of successive stages of study in technical, economic, legal/institutional, and financial aspects of reuse as they apply to your community. Just as crucial to successful program implementation is your support and encouragement, from the outset, of active public involvement in the reuse-planning process.

Why Public Participation?

Public involvement begins with your earliest exploratory contacts with potential users, and can continue through to formation of an advisory committee and holding of nonbinding referenda on candidate reuse schemes. It involves the two-way flow of information and responses, helping to ensure that adoption of a selected water-reuse program will fulfill real user needs and generally-recognized community goals.

SOURCE OF INFORMATION

The term "two-way flow" cannot be too highly emphasized. From the point of view of sound planning, your encouragement of public participation will uncover community information and resources that can substantively affect the reclamation/reuse plan. As stated in EPA's *Public Involvement Activities Guide:* "Local residents often have a more intimate understanding of particular community problems... Their information is pertinent and up-to-date... (reflecting) the community's values, concerns, and goals."[1] The distinction that engineers often make between a proposal's technical merit and its local political acceptability is often an artificial one. Citizens have legitimate concerns, quite often reflecting their knowledge of detailed technical information. In reuse planning, especially, where one sector of "the public" comprises potential users of reclaimed water, this point pertains all the more strongly. Potential users know what flow and quality of reclaimed water are acceptable for their applications. The example from Chicago-South End of Lake Michigan discussed at the end of this chapter illustrates that an agency's failure to consult at an early stage with affected segments of the public undermined not only the acceptability of its proposed program, but also its intrinsic technical merit.

INFORMED CONSTITUENCY

Beyond the value of public participation in improving your base of information is the fact that by soliciting expression of public concerns and incorporating suggestions made by members of the public, you can also build, over time, an informed constituency that is "at home" with the concept of reuse, knowledgeable about the trade-offs involved in reclamation/reuse, and supportive of program implementation. Citizens who have taken part in the planning process will be effective proponents of the selected plans. Having educated themselves on the trade-offs involved in adopting reclamation and reuse, they will understand how various interests have been accommodated in the final plan. Their understanding of the decision-making process will, in turn, be communicated to the larger interest groups—neighborhood residents, clubs, and municipal agencies—of which they are a part.

Since most reuse programs will ultimately require the direct involvement of the voting public anyway—say, in voting to support a bond issue necessary to fund reuse system capital improvements, you can avoid the "sudden-death" overtones of such a vote by diligently soliciting information, viewpoints and criticism early in the planning process, even as you are beginning to identify alternatives. You will also be gaining time at the front end, and time in itself is crucial to allow dissemination and acceptance of new ideas among public sectors.[2] If your program is likely to encounter opposition in the community, support of public participation will uncover opposition early enough in planning so that the opposition's concerns can be addressed, or so that you can be prepared for continued opposition up to and through program implementation. Precedents for failure to take these steps are legion in wastewater-facilities planning, and lie behind EPA's adoption in 1979 of amended regulations providing for more significant levels of public participation in Section 201-funded projects.[3]

Defining "The Public"

Many contemporary analyses of public involvement define "the public" as comprising various subsets of "publics" with differing interests, motivations, and approaches to policy issues. For example, in discussing public participation for wastewater facilities planning, one planning consultant identifies the following publics: general public, potential users, environmental groups, regulators, political leaders, and business/academic/community leaders.[4]

EPA regulations[5] identify the public as the general public, the organized public (public and private interest groups), the representative public (elected and appointed officials), and the economically concerned public (in this case, those whose interests might be directly affected by a reuse program). Examples of groups falling under the organized, representative and economically concerned publics can include the news media and "the chief elected officials of the involved communities, neighborhood organizations, the 208 Citizens Advisory Committee, the Sierra Club, the League of Women Voters, business groups such as the Chamber of Commerce, the Rotary Club, industries and unions, sportsmen's clubs, historical societies, public works departments, recreation commissions, health departments, and state legislations."[6]

Will you need to involve all sectors of the public in reuse planning?

If your program for reuse truly has minimal impact on the general public, you might need to solicit information and support only from technical and health experts in other municipal and state agencies and from representatives of the prospective user and its employees. Use of treatment plant effluent as industrial cooling water—with no significant capital improvements required of the municipality—might fall in this category. Reuse for irrigation of pasture land in well-isolated areas might be another example.

But consideration of a broad range of candidate reuse systems, as is being advocated in these *Guidelines*, involves choices among systems with widely varying economic and environmental impacts for many segments of the public. Successful plan implementation will be assured only when officials, interest groups, and ordinary citizens share "a significant voice in (project) development."[7]

"The public," in reuse planning, encompasses area residents, potential users of reclaimed water, freshwater purveyors, citizens with special areas of expertise pertinent to reuse, and the interest groups whose support is vital as representing diverse viewpoints shared by many in the community. From the outset of your reuse planning, informal consultation with members of each of these groups, and your formal presentations before them, should both support the development of a sound base of local water-reuse information and, simultaneously, build a coalition that can effectively advocate reuse in the community. Keeping in mind that different groups have different interests at stake, you will want to tailor your consultations with these groups to be sure you are addressing the issues of concern to them in the terms they understand.

Before turning to some possible methods of achieving these goals, what public reaction to reuse might you expect?

Gauging Public Acceptance

You might be surprised to find a large measure of local public support for reuse programs. A number of opinion surveys conducted in recent years have shown similar trends in public acceptance of reuse: studies completed by Bruvold and Ward[8] and by Bruvold and Crook,[9] for example, show high (more than 90 percent) acceptance for so-called "low-level" reuse applications, with public support gradually eroding as the risk of exposure to reclaimed water increased. The author of another study[10] obtained similar results, concluding that "for lower contact uses, public attitudes are largely accepting...(The) public is ready for large-scale wastewater reuse for non-body-contact purposes." Even when surveys have focused on possible reuse for **potable** purposes,[11,12] anywhere from 48 to 62 percent of the respondents have indicated a willingness to use "renovated" wastewater.

These survey results and others have led some investigators to conclude that public officials have lagged behind the public in their enthusiasm for reuse, and certainly in their assessment of public opinion on reuse (e.g.,[10]). One study[11] funded by the U.S. Office of Water Resources Research (now the Office of Water Research and Technology), U.S. Department of the Interior, concluded that "Government officials...grossly underestimated public opinion (toward reuse)," and that government officials' objections to wastewater reuse on the basis of supposed adverse public opinion, at least in the case of body contact and some non-body-contact uses, "lack a substantial foundation." Another author[12] is even more critical in evaluating the role of public officials: "the salient impediment (to reuse) may lie in the minds of the engineers and water management officials who for a variety of reasons are themselves reluctant to move to what is for them a revolution in water supply management, fraught with uncertainty and risk" (Figure 6-1).

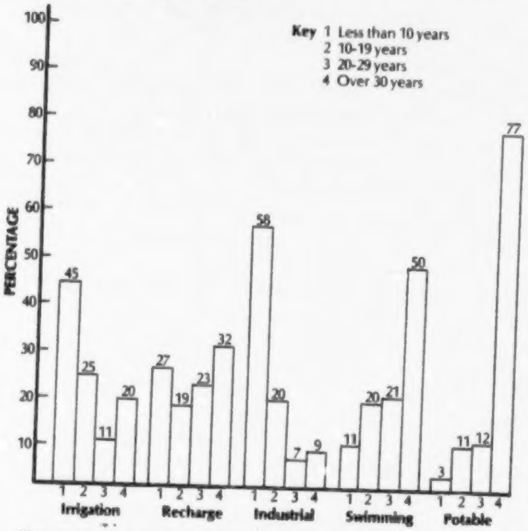

Figure 6-1. Survey of public officials and consulting engineers in water-abundant New England showed very conservative attitudes toward reuse, although about half of those interviewed saw industrial or irrigation reuse being adopted in the region within ten years. The same study indicated that those most directly involved in assessment of reuse opportunities respond to the reuse concept according to their areas of responsibility: municipal officials judge reuse on the basis of its operability, as compared to other supply-augmenting options; consulting engineers are concerned with reliability and costs; state officials, with public-health issues; and regional EPA personnel, with funding of cost-effective projects. (Source: Johnson, B.B. Waste Water Reuse and Water Quality Planning in New England: Attitudes and Adoption. Water Resources Research 15:6, December 1979. pp 1329-1334.)

Of course, these bad reviews tend to obscure the fact that most public officials who might undertake implementation of a water-reuse program have received their "battle scars" in previous encounters with the public on issues as ostensibly straightforward as the routing of a new sewer line. Some authors have even attempted to link public officials' supposed wariness on the reuse issue to their "dread of public controversy" gained in the "bitter and bizarre debates over fluoridation."[12,13] Others have attributed it to long-established priorities, in water-abundant areas such as New England, of providing all water supply from protected upland reservoirs.[10]

Whatever the reasons behind public officials' poor view of public opinion on water reuse, there is no question that the public's enthusiasm for reuse (as perceived in the cited studies) might more reflect the hypothetical conditions set up by the survey questions and interviews used than signify a genuine willingness to endorse local funding of real programs that could involve distribution of reclaimed water for nonpotable use in their neighborhood. The survey results do indicate, however, that at least on the intellectual plane, "the public" is receptive to use of reclaimed water in well-thought-out programs. The results also support conclusions that this initial acceptance hinges in large measure on:

- the public's awareness of local water-supply problems and perception of reclaimed water as having a place in the overall water-supply allocation scheme;[11]
- public understanding of the quality of reclaimed water and how it would be used;
- confidence in local management of the public utilities and in local application of modern technology (Stone[11] found that residents in communities with good-quality water were more accepting of the use of reclaimed water than were residents in communities with water-quality problems); and
- assurance that the reuse applications being considered involve minimal risk of accidental personal exposure.

Bruvold and Ongerth[14] conclude that "the public is not yet ready for intimate uses of reclaimed water...(nor does the public favor) a low level of treatment of wastewater and its discharge into the environment without further reuse." Having set these boundaries of public acceptance, it is time to turn to specific recommendations on public information and involvement in reuse planning.

CASE STUDY:
Potential Users' Workshops and Reuse Planning

Where conditions for reuse are particularly sensitive, a program of public involvement is essential to gain potential users' commitment to reclaimed water. Such is the case in Goleta, California, where a pilot plant demonstration program was completed during 1979 as one spinoff of public participation to date.

The Goleta County Water District's (GCWD) planning for water reclamation and reuse represents an attempt to solve a severe water shortage that has clamped a moratorium on new water-system connections since 1972. Even with concerted conservation efforts, the District operates at a 1,500 acre-foot/year deficit. Of the current total demand of 19,000 acre-feet/year, agricultural irrigation accounts for about one-fourth, a proportion projected to increase to one-third by 1990.

In order to end the deficit and to lift the moratorium on water system hookups, the District undertook a "201"-funded facility planning study of water-reclamation/reuse alternatives. (Currently, wastewater receives primary sedimentation prior to ocean disposal.) GCWD found that substitution of reclaimed water for landscape and agricultural irrigation would free potable-water supplies, but that the high TDS (1,330 mg/l) of untreated effluent would cause problems, particularly for the highly sensitive avocado and citrus crops grown in the area. Accordingly, GCWD and its engineering consultants undertook a series of meetings and workshops with representatives of major growers.

In the workshops, the participants worked cooperatively to identify potential sites for irrigation with reclaimed water and to review current irrigation practices and discuss areas of concern. The growers expressed concern that minerals in the reclaimed water would accumulate in the soils and cause reduced productivity over the long term; most growers stated they would not accept substitution with reclaimed water unless quality and costs were comparable to their current supplies.

Technical studies showed the desired water quality could be achieved by coagulant addition, rapid-mixing, filtration and reverse osmosis of the secondary effluent from the new Goleta plant. A blend of wastewater receiving 75 percent treatment by reverse osmosis would yield water quality comparable to local surface supplies (445 mg/l TDS, as opposed to 523 mg/l from the Cachuma Reservoir) and better than available ground water. Both reservoir water and 75 percent RO reclaimed water carry a seven-percent leaching requirement. The engineers recommended a two-phased approach to reuse: while Phase I reuse will involve only landscape irrigation, using disinfected secondary effluent, Phase II will provide reclaimed water for irrigation of some 4,970 acres of avocado and citrus groves. Total Phase II use is expected to total 7,653 acre-feet per year.

The 5,000-gpd pilot demonstration program is being conducted, with federal and state assistance, both to obtain detailed operating performance data on the reverse osmosis unit and to obtain firm commitments from growers as a result of demonstrated treatment performance.

To date, the workshops and demonstration program have helped support reuse goals in Goleta: in 1979 voters participating in a GCWD advisory election mandated the District to proceed with the reclamation project and to study means of funding the local share.[16]

Source: Everest, W. R. and R. A. Paul. Reclaimed Wastewater as a Feasible Water Resource for Landscape and Orchard Irrigation. In: Proceedings of the Water Reuse Symposium, Vol. 3. AWWA Research Foundation. Denver, Colorado, 1979. pp. 2082-2103.

Involving the Public in Reuse Planning

Most studies of public attitudes toward reclamation and reuse which are reported in the literature appear to focus more on management of public opinion than on the actual involvement of the public in making decisions about reclamation and reuse projects for which they are asked to pay. Strategies are recommended for identifying the source of public reaction against reuse, whether it be cost,[15] "psychological repugnance,"[8] or ignorance about the overall water-supply problem,[11] and then responding with a public-information campaign developed specifically to offset the identified public sentiment. Sims and Baumann, for example, have concluded that unless perceived experts share a "congruence of belief" in the viability of reuse, any public information program would fail.[13] They suggest, therefore, that experts must reach a consensus of opinion and then "present the public with information that would reflect more solid support among the experts." Moreover, having concluded that ignorance about or lack of faith in water-treatment science and technology are the primary factors behind aversion toward reuse, Sims and Baumann recommend "an information campaign that would focus upon encouraging public support, not one based upon enhancing public dialogue."

The investigators' assumptions appear to be that reclamation/reuse is clearly a desirable goal wherever there is a threat of water-supply shortages, and that the public official must convince the public of this fact. As we have emphasized repeatedly in these *Guidelines*, however, water reuse is only one water-supply alternative to be considered, among many, and reuse planning is rarely carried out in an economic and political vacuum. Democratic imperatives alone require a more realistic and straightforward approach to public involvement. Specific techniques to effect this approach are discussed in the following paragraphs.

CLEAN WATER ACT REQUIREMENTS FOR PUBLIC PARTICIPATION

The starting point for any reuse program that could involve Clean Water Act funding is, of course, the amended public-participation requirements contained in §35.917-5, 40 CFR Part 35 Subpart E (Federal Register Vol. 44, No. 34, February 16, 1979). The application of these requirements to wastewater-facilities planning has been illustrated by Heilman[4] as adapted in Figure 6-2. The "abbreviated" or "basic" program involves, at a minimum, initial public consultation and three structured events involving public dialogue. The "full-scale" program for more complex "201" projects includes, in addition, the designation of a public participation

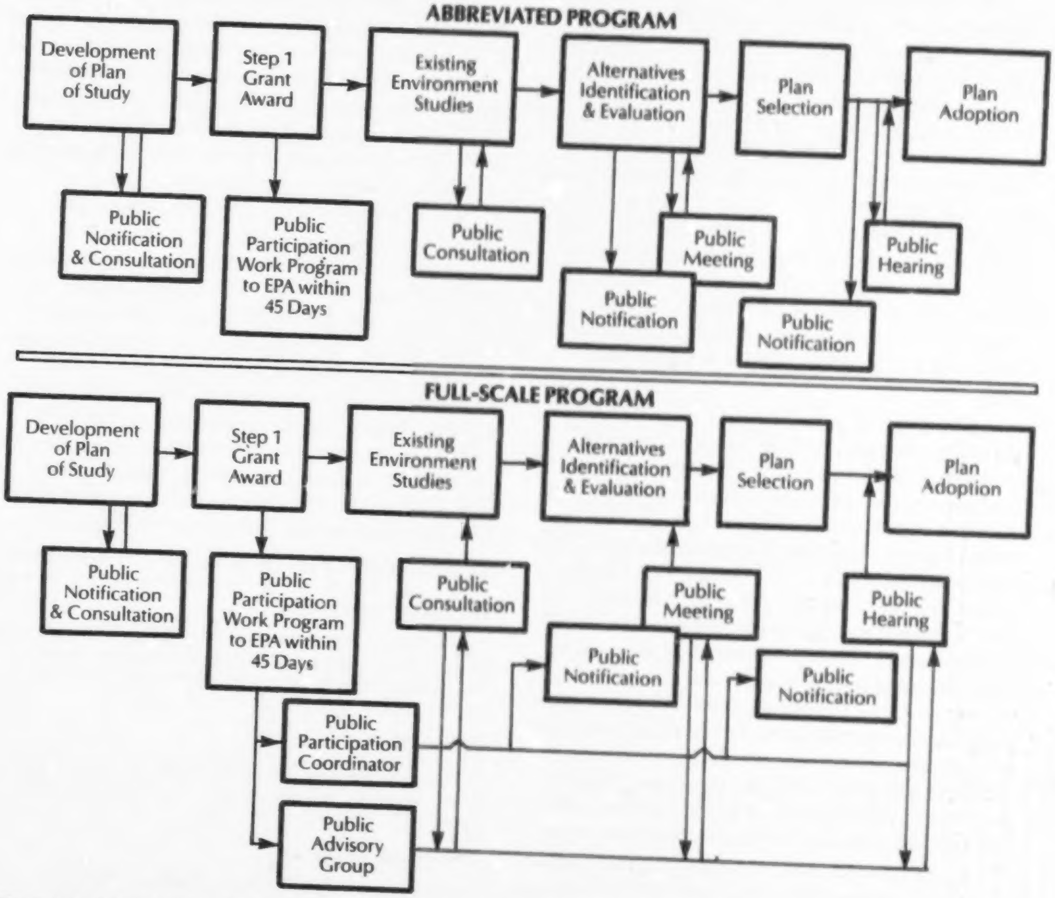
ABBREVIATED PROGRAM
Development of Plan of Study
Step 1 Grant Award
Existing Environment Studies
Alternatives Identification & Evaluation
Plan Selection
Plan Adoption
Public Notification & Consultation
Public Participation Work Program to EPA within 45 Days
Public Consultation
Public Meeting
Public Hearing
Public Notification
Public Notification
FULL-SCALE PROGRAM
Development of Plan of Study
Step 1 Grant Award
Existing Environment Studies
Alternatives Identification & Evaluation
Plan Selection
Plan Adoption
Public Notification & Consultation
Public Participation Work Program to EPA within 45 Days
Public Consultation
Public Meeting
Public Hearing
Public Notification
Public Notification
Public Participation Coordinator
Public Advisory Group

Figure 6-2. Abbreviated and full-scale public participation programs required for Section 201 wastewater facilities planning can apply as well to planning a program of water reuse. (Source: Heilman, C.B. Join Forces with John Q. Public. Water & Wastes Engineering, July 1979. pp. 26-28.)

coordinator to serve through the duration of the project, and establishment of a public advisory group.

Either program can be adapted effectively to the planning sequence recommended in Chapter 1 of these *Guidelines*, whether or not you actually intend to use "201" funding. The ongoing "public consultation" required prior to identifying and screening of alternatives in wastewater-facilities planning corresponds well to public involvement in the preliminary investigations of reuse planning. This could encompass initial contacts with other public agencies that can provide basic information on water use or regulatory requirements, informal discussions with some potential users to determine interest or fill data gaps, and initial background reports to appropriate local decision-making bodies.

You might find it helpful to identify at the outset the level of interest different individuals and groups will have in the reuse-planning process. For example, Boston's Metropolitan District Commission (MDC) determined in one recent "201"-related public-participation program that some "publics" would want only to be kept informed on a regular basis, some would want periodic opportunities to ask questions and offer comments, and some would want to play a very active review and advisory role.[6] The MDC's public-participation program incorporated tasks and activities that ensured the desired degree of involvement for each group. Table 6-1 lists tools of public participation that might be useful in informing and involving the public to different degrees.

If the scope or potential scope of your reuse planning warrants it—if, for example, you are considering distribution of reclaimed water to several users or types of users—formation of a public advisory group at this stage will assist you in defining system features and resolving problem areas. In its regulations for full-scale public-participation programs, EPA requires that group membership contain "substantially equivalent" representation of the private (noninterested), organized, representative and affected segments of the public. We would recommend that group membership for reuse planning provide representation for potential users and their employees, interest groups, neighborhood residents, the other public agencies, and citizens with specialized expertise in areas (such as public health) that pertain directly to reclamation/reuse.

There is no reason to consider the group fixed at its original membership; other interested citizens can be co-opted as the reuse program takes shape and as new issues or opportunities develop. What is important, however, is to institutionalize the group and its activities so that its efforts are directed effectively to the task at hand: planning and implementation of a reuse program in which the legitimate interests of various sectors of the public have been fully considered and addressed. In order to achieve this, you should publicize the proposed formation of the advisory group and solicit recommendations for, and expression of interest in, membership.

The group's responsibilities should be well-defined, whether you intend that the group should simply conduct a study of some particular aspect of the reuse plan, or that it should serve throughout program planning and implementation as a broad-based representative body that can develop and advocate the program. Its meetings should be open to the public at times and places announced in advance. The group's members should designate at an early meeting a single individual who can serve as a contact-point for the press and other news media. The group should fully recognize its shared responsibility for developing a sound reuse program that can serve both user requirements and community objectives. In subsequent public meetings, the group will assert its combined role as source of information representing numerous interests, and advocate of the reuse program as it gains definition.

Other EPA regulations for full-scale public-participation programs under Part 35 require appointment of a public-participation coordinator—an individual skilled in developing, publicizing, and conducting informal briefings and work sessions as well as formal presentations for various community groups. Whether or not your program requires designation of a public-participation specialist, you should consider the significant value of providing public contact and liaison through a single individual. Such a person, whether an agency staffer, advisory group member or specialist engaged from the larger community, should be thoroughly

Table 6-1. THE TOOLS OF PUBLIC PARTICIPATION*

Education/Information
Newspaper articles, radio and TV programs, speeches and presentations, field trips, exhibits, information depositories, school programs, films, brochures and newsletters, reports, letters, conferences.
Review/Reaction
Briefings, public meetings, public hearings, surveys and questionnaires, question-and-answer columns, advertised "hotlines" for telephone inquiries.
Interaction/Dialogue
Workshops, special task forces, interviews, advisory boards, informal contacts, study-group discussions, seminars.

*from[1] and other sources

informed of reuse-planning progress, be objective in presenting information, and have the "clout" necessary to communicate and get fast response on issues or problems raised during program planning and implementation. An individual who is recognized in the community as filling these roles can greatly facilitate the flow of information in each direction.

The timing of the public meeting required in changes to 40 CFR "when alternatives are largely developed but before an alternative or plan has been selected"[3] corresponds to the screening of potential markets recommended in Chapter 1 of these *Guidelines*. At this meeting, you can present for public scrutiny the list of reuse/non-reuse alternatives developed for consideration; an outline of assumptions and criteria that will be used as this list is first screened; and then evaluation in detail (see the discussions in Chapter 1 of procedures used by East Bay Dischargers Authority and by East Bay Municipal Utility District). You should encourage and be prepared to accept proposed additions or modifications to the base of information you have prepared at this time.

The closer you are to selection of a reuse-program alternative, the more specific will be the issues remaining to be resolved. Now is the time to seek direct, organized participation of potential users in developing and evaluating details of the planned program (see, for example, the Goleta case study). This can be achieved by establishing an advisory group of users (if you have not already created a public advisory group) or by asking the public advisory group to set up a directed study subcommittee staffed by potential users and others with specific pertinent expertise.

In "201" planning, the final structured element of public participation involves **a formal public hearing** "before final adoption of the facilities plan." **This would logically follow the detailed evaluation of potential markets discussed in Chapter 1,** if the project were to qualify for Clean Water Act funding. If you were not considering use of "201" funds and your project involved a single public or private user, with little or no impact on the general public, it would not be necessary to hold a public hearing. Obviously, however, supporting continued public participation, as a follow-through measure, would provide added assurance that future expansion of the system to serve other users and markets could be more easily achieved.

Bruvold and Crook have recently urged that a direct solicitation of public opinion precede selection of a treatment/reuse alternative.[9] This might take the form of a non-binding referendum, asking voters to select among, say, three candidate reclamation schemes that "deliberately represent divergent solutions," possibly ranging from treatment/disposal to advanced treatment/high-level reuse. In the weeks before the referendum, a voter information packet could be distributed containing a description of each option, summaries of the environmental, economic and health aspects of each, and position statements by opposing groups. The effort could be accompanied by meetings and media coverage; the authors concede that all this "would cost money" but probably would be "less costly in money and confidence in public officials" than failure to provide some form of early, broad-based citizen involvement. Too often, they say, "technical experts and political planners can misjudge the public will...The bond issue vote on (only) one option chosen by the experts weighs too heavily in favor of technocratic expertise and too lightly for democratic principles." Bruvold and Crook cite the failure of the innovative and widely publicized Santee, California recreational reuse facility as an example of what can happen when there is insufficient public support for funding facilities favored by "the technical and local political sectors."

A CASE IN POINT

In 1972, the Corps of Engineers revealed plans for a program to provide land treatment, in four rural counties in northwestern Indiana, of wastewater piped from a highly industrialized area at the south end of Lake Michigan. Galloway has completed a case study and critique[16] of the public reaction and "solid front of opposition" stirred by the proposal, which was shelved after more than a year of intense public controversy. Galloway sees the Corps' failure to consult with the public until within two weeks of a public hearing on the proposal as a crucial flaw that not only fostered an abiding sense of mistrust among rural residents, but also limited even the amount of technical information the Corps needed to develop a sound plan. (For example, the proposed irrigation rates of 134 inches annually would have been far too high for the region's poorly drained sandy and loamy soils and high water table. Farmers feared they would be forced to change cropping patterns or to sell their land under these conditions.) Despite the Corps' attempts to restore public confidence in the proposal by engaging the services of Indiana Cooperative Extension Service agents, and sincere efforts to respond to local criticisms of the plan, the Corps was never able to overcome the inertia of initial opposition to the plan.

Galloway concludes that the Chicago-South End of Lake Michigan plan typifies experiences likely to occur in planning for wastewater reclamation/reuse in other "urban-rural fringe areas." Opportunity costs often are particularly high in such areas, adding to the economic burden of any land-based proposal. Among his conclusions:

- The Cooperative Extension Service or other educational agency should be involved from the outset in planning for this type of reuse.
- Public education programs should be guided by local citizens' committees representing all citizen concerns.
- Programs should provide two-way flow of information through small-group discussions and presentations. The public hearing process "results in more controversy than education," says Galloway.
- A program should assure ongoing contact between the local/state agencies that will be involved.
- Broad changes in scope, location, type of use, or use rates should be minimized, as changes in such basic direction can lower public confidence in the planners' understanding of technical issues.

Above all, Galloway argues, planners and agencies "must eliminate biases toward favored treatment alternatives" and must be well-informed enough to handle discussions of technical or agronomic issues skillfully. Users and the general public will have legitimate concerns that must be duly addressed in the planning process.

Galloway's concluding remarks provide a fitting closing to this chapter:

"Good educational programs...cannot assure public acceptance of land treatment...If they are well-conceived and executed, they can result in a public well enough informed to make logical choices and support decision makers and officials who will have to decide on adopting wastewater treatment systems in the years ahead."

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Appendix A

Research Needs for Nonpotable Water Reuse

The following research needs would assist in the development of nonpotable reuse programs:

Impact of Treatment on Viruses. Because we do not have a routine determination for viruses, it would be useful to have correlations developed for different methods of treating wastewaters to establish relationships between the routine bacterial determinations and the presence of viruses in the reclaimed water for various types of wastewater and treatment methods.

Impact of Aerosolized Viruses. Major reuse applications are in the spray irrigation of lawns, median strips and shoulders on roadways, parks and playgrounds, and in the cooling towers of power plants. In these applications, as contrasted with agricultural reuse, there exists the potential for exposure of a large segment of the population to the sprays. This makes the virus problem somewhat more serious than in the case when only a few people might be exposed, as in the case of agricultural spraying or at wastewater treatment plants. Some work has been done in detecting bacteria in these sprays and plumes, but almost no work has been done in identifying viruses.

The persistence of viruses in air drying on sprayed areas should also be established. One of the guidelines for reuse might be that the spray irrigation be done in the evening, with use of the sprayed fields—such as tennis courts and golf courses—during the daylight hours. More information concerning the time element that should be provided between spraying and contact is required.

Water Quality Standards for Nonpotable Reuse. Standards must be developed for various nonpotable uses. In the case of nonpotable distribution systems, it is necessary that the standards meet the requirements for the highest use. Standards have been developed for many nonpotable uses, especially in California. But the standards are needed for nonpotable **systems** as well as for such uses as toilet flushing and residential irrigation. In connection with such standards, protocols for monitoring of such systems need to be developed, including frequency and method of sampling.

Studies of Wastewater Filtration. Experience and research at Pomona, California has demonstrated that minimum treatment to assure quality of the nonpotable supply will include filtration of the wastewater treatment plant effluent. Some studies in this regard have been done, but not with the intention of meeting a standard for reuse. Far more attention needs to be given to direct filtration of effluents with the use of coagulants or coagulant aids.

Distribution System Maintenance. Because there has been no extensive monitoring of nonpotable systems, we have little data on the fate of chlorine residuals in distribution systems for nonpotable waters. We can expect that slimes will grow, and we should obtain data on such growths, with the intention of devising control methods, such as periodic intensive chlorination, should this be necessary. As noted above, nonpotable systems will need to be monitored for bacteria in much the same way that potable systems are now being monitored. However, we do not know what standards should be applied to such systems, and research in this area would be extremely helpful.

Documentation of Experience at Reuse Systems. Nonpotable systems where many and diverse customers make use of the reclaimed wastewater are few in number and relatively new. Accordingly, it might be well to profit from these innovative applications and to assist the agencies operating them to assemble data based upon their operations. Data so collected would be extremely useful to others who might seek to initiate nonpotable distribution systems.

Intensive Monitoring Program. Many innovative nonpotable reuse systems are being introduced. Regulatory agencies are understandably cautious and would tend to impose monitoring requirements that may seem excessive, but are necessary because of the lack of experience with such systems. It would be entirely appropriate to use research funds to assist with the additional monitoring required during the early days of such systems. Once there is experience with nonpotable systems, the level of monitoring could be sharply reduced.

Appendix B

State and Federal Environmental Agencies

STATE ENVIRONMENTAL AGENCIES

State	Overall Responsibility	Wastewater Responsibility
Alabama	Chief Engineer & Director Environmental Health Administration State Office Building Montgomery, AL 36130 (205) 832-3176	Water Improvement Comm. State Office Building Montgomery, AL 36130 (205) 277-3630
Alaska	Commissioner Department of Environmental Conservation Pouch O Juneau, AK 99811 (907) 465-2600	Division of Water Programs Department of Environmental Conservation Pouch O Juneau, AK 99811 (907) 465-2640
Arizona	Director Division of Environmental Health Services 1740 West Adams Street Phoenix, AZ 85007 (602) 255-1130	Division of Environmental Health Services Bureau of Water Quality Control 1740 West Adams Street Phoenix, AZ 85007 (602) 255-1252
Arkansas	Director Department of Pollution Control & Ecology 8001 National Drive Little Rock, AR 72219 (501) 371-1701	Department of Pollution Control & Ecology 8001 National Drive Little Rock, AR 72219 (501) 371-1701
California	Secretary for Resources The Resources Agency 1416 Ninth Street Sacramento, CA 95814 (916) 445-5656	Water Resources Control Board P.O. Box 100 Sacramento, CA 95801 (916) 445-7762
Colorado	Executive Director Department of Health 4210 East 11th Avenue Denver, CO 80220 (303) 320-8333, ext. 3315	Water Pollution Control Division Department of Health 4210 East 11th Avenue Denver, CO 80220 (303) 320-8333
Connecticut	Commissioner Department of Environmental Protection State Office Building 165 Capitol Avenue Hartford, CT 06115 (203) 566-2110	Department of Environmental Protection State Office Building 122 Washington Street Hartford, CT 06115 (203) 566-5599
Delaware	Secretary Department of Natural Resources & Environmental Control P.O. Box 1401 Dover, DE 19901 (302) 678-4403	Division of Environmental Control Department of Natural Resources & Environmental Control P.O. Box 1401 Dover, DE 19901 (302) 678-4765
District of Columbia	Director Department of Environmental Services 415 12th Street N.W. Washington, DC 20004 (202) 629-3415	Water Quality Division Department of Environmental Services 5010 Overlook Avenue S.W. Washington, DC 20002 (202) 767-7486

STATE ENVIRONMENTAL AGENCIES (continued)

State	Overall Responsibility	Wastewater Responsibility
Florida	Secretary Department of Environmental Regulation 2600 Blair Stone Road Tallahassee, FL 32301 (904) 488-4807	Division of Environmental Programs Department of Environmental Regulation 2600 Blair Stone Road Tallahassee, FL 32301 (904) 487-8163
Georgia	Director Environmental Protection Division Department of Natural Resources 270 Washington Street S.W., Room 822 Atlanta, GA 30334 (404) 656-4713	Environmental Protection Division Department of Natural Resources 270 Washington Street S.W., Room 822 Atlanta, GA 30334 (404) 656-6593
Hawaii	Director of Health Hawaii State Department of Health P.O. Box 3378 Honolulu, HI 96801 (808) 548-6505	Environmental Health Division Hawaii State Department of Health P.O. Box 3378 Honolulu, HI 96801 (808) 548-4139
Idaho	Department of Health & Welfare Division of Environment Statehouse Boise, ID 83720 (208) 384-2393	Department of Health & Welfare Division of Environment Statehouse Boise, ID 83720 (208) 384-2433
Illinois	Director Environmental Protection Agency 2200 Churchill Road Springfield, IL 62706 (217) 782-3397	Division of Water Pollution Control Environmental Protection Agency 2200 Churchill Road Springfield, IL 62706 (217) 782-9540
Indiana	Secretary State Board of Health 1330 West Michigan Street Indianapolis, IN 46206 (317) 633-8854	Director Division of Water Pollution Control State Board of Health 1330 West Michigan Street Indianapolis, IN 46206 (317) 633-8862
Iowa	Executive Director Department of Environmental Quality Henry A. Wallace Building 900 East Grand Des Moines, IA 50319 (515) 281-8690	Water Quality Management Division Department of Environmental Quality Henry A. Wallace Building 900 East Grand Des Moines, IA 50319 (515) 281-8690
Kansas	Director Division of Environment Department of Health & Environment Topeka, KS 66620 (913) 862-8690	Bureau of Water Quality Division of Environment Department of Health & Environment Topeka, KS 66620 (913) 862-9360
Kentucky	Commissioner Bureau of Environmental Protection Department of Natural Resources & Environmental Protection Capital Plaza Towers Frankfort, KY 40601 (502) 564-2150	Division of Water Quality Department of Natural Resources & Environmental Protection Century Plaza U.S. 127 South Frankfort, KY 40601 (502) 564-3410
Louisiana	Office of Health Services & Environmental Quality P.O. Box 60630 New Orleans, LA 70160 (504) 568-5100	Stream Control Commission P.O. Box Drawer FC University Station Baton Rouge, LA 70803 (504) 389-5309
Maine	Commissioner Department of Environmental Protection State House Augusta, ME 04333 (207) 289-2811	Bureau of Water Pollution Control Department of Environmental Protection State House Augusta, ME 04333 (207) 289-2591

STATE ENVIRONMENTAL AGENCIES (continued)

State	Overall Responsibility	Wastewater Responsibility
Maryland	Environmental Health Administration Department of Health & Mental Hygiene 201 West Preston Street Baltimore, MD 21201 (301) 383-2740	Water Resources Administration Department of Natural Resources Annapolis, MD 21401 (301) 269-3846
Massachusetts	Secretary Executive Office of Environmental Affairs 100 Cambridge Street Boston, MA 02202 (617) 727-9800	Division of Water Pollution Control Department of Environmental Quality Engineering 110 Tremont Street Boston, MA 02202 (617) 727-3855
Michigan	Chief Bureau of Environmental Protection Department of Natural Resources P.O. Box 30028 Lansing, MI 48909 (517) 373-7917	Water Quality Division Department of Natural Resources P.O. Box 30028 Lansing, MI 48909 (517) 373-1947
Minnesota	Executive Director Pollution Control Agency 1935 West County Road B2 Roseville, MN 55113 (612) 296-7301	Pollution Control Agency Division of Water Quality 1935 West County Road B2 Roseville, MN 55113 (612) 296-7203
Mississippi	Executive Director Air & Water Pollution Control Commission P.O. Box 827 Jackson, MS 39205 (601) 354-2550	Division of Water Pollution Control Air & Water Pollution Control Commission P.O. Box 827 Jackson, MS 39205 (601) 354-2550
Missouri	Director Division of Environmental Quality P.O. Box 1368 Jefferson City, MO 65102 (314) 751-3241	Water Quality Program Division of Environmental Quality P.O. Box 1368 Jefferson City, MO 65102 (314) 751-3241
Montana	Administrator Environmental Sciences Division Department of Health & Environmental Sciences Board of Health Building Helena, MT 59601 (406) 449-3946	Water Quality Bureau Department of Health & Environmental Sciences 555 Fuller Helena, MT 59601 (406) 449-2406
Nebraska	Director Department of Environmental Control P.O. Box 94877, State House Station Lincoln, NB 68509 (402) 471-2186	Department of Environmental Water Pollution Control P.O. Box 94877, State House Station Lincoln, NB 68509 (402) 471-2186
Nevada	Director Department of Conservation & Natural Resources 201 South Fall Street, Capitol Complex Carson City, NV 89710 (702) 885-4360	Department of Conservation & Natural Resources Division of Environmental Protection 201 South Fall Street, Capitol Complex Carson City, NV 89710 (702) 885-4670
New Hampshire		Water Supply & Pollution Control Commission 105 Loudon Road, P.O. Box 95 Concord, NH 03301 (603) 271-3503
New Jersey	Commissioner Department of Environmental Protection P.O. Box 1390 Trenton, NJ 08625 (609) 292-2885	Division of Water Resources Department of Environmental Protection P.O. Box CN029 Trenton, NJ 08625 (609) 292-0666

STATE ENVIRONMENTAL AGENCIES (continued)

State	Overall Responsibility	Wastewater Responsibility
New Mexico	Director Environmental Improvement Division P.O. Box 968 Santa Fe, NM 87503 (505) 827-5271	Water Pollution Control Section Environmental Improvement Agency P.O. Box 968 Santa Fe, NM 87503 (505) 827-5271
New York	Commissioner Department of Environmental Conservation 50 Wolf Road Albany, NY 12233 (518) 457-3446	Division of Pure Waters Department of Environmental Conservation 50 Wolf Road Albany, NY 12233 (518) 457-6674
North Carolina	Director Division of Environmental Management Department of Natural Resources & Community Development P.O. Box 27687 Raleigh, NC 27611 (919) 733-7015	Division of Environmental Management Department of Natural Resources & Community Development P.O. Box 27687 Raleigh, NC 27611 (919) 733-7120
North Dakota	Chief Environmental Health & Engineering Services Executive Offices State Department of Health State Capitol Bismarck, ND 58501 (701) 224-2371	Division of Water Supply & Pollution Control Department of Health State Capitol Bismarck, ND 58501 (701) 224-2354
Ohio	Director Environmental Protection Agency P.O. Box 1049 Columbus, OH 43216 (614) 466-8318	Division of Water Pollution Control Environmental Protection Agency P.O. Box 1049 Columbus, OH 43216 (614) 466-2390
Oklahoma	Director Department of Pollution Control Box 53504 N.E. 10th & Stonewall Oklahoma City, OK 73152 (405) 271-4677	Water Resources Board Jim Thorpe Building, 5th Floor Oklahoma City, OK 73152 (405) 521-3945
Oregon	Department of Environmental Quality P.O. Box 1760 Portland, OR 97207 (503) 229-5696	Water Quality Control Division Department of Environmental Quality P.O. Box 1760 Portland, OR 97207 (503) 229-6474
Pennsylvania	Secretary Department of Environmental Resources P.O. Box 1467 Harrisburg, PA 17120 (717) 787-2814	Bureau of Water Quality Management Department of Environmental Resources P.O. Box 2063 Harrisburg, PA 17120 (717) 787-2666
Puerto Rico	Chairman Environmental Quality Board P.O. Box 11488 Santurce, PR 00910 (809) 725-5140	Associate Member Air and Water Environmental Quality Board P.O. Box 11488 Santurce, PR 00910 (809) 725-8692
Rhode Island	Director Environmental Management 83 Park Street Providence, RI 02903 (401) 277-2771	Department of Environmental Management Cannon Building, Room 209 75 Davis Street Providence, RI 02908 (401) 277-2234
South Carolina	Commissioner Department of Health & Environmental Control 2600 Bull Street Columbia, SC 29201 (803) 758-5443	Division of Water Quality Department of Health & Environmental Control 2600 Bull Street Columbia, SC 29201 (803) 758-5483

STATE ENVIRONMENTAL AGENCIES (continued)

State	Overall Responsibility	Wastewater Responsibility
South Dakota	Secretary Department of Environmental Protection Joe Foss Building Pierre, SD 57501 (605) 773-3351	Water Quality Program Department of Environmental Protection Joe Foss Building Pierre, SD 57501 (605) 773-3296
Tennessee	Director Bureau of Environmental Health Services Department of Public Health 349 Cordell Hull Building Nashville, TN 37219 (615) 741-3657	Division of Water Quality Control Department of Public Health 621 Cordell Hull Building Nashville, TN 37219 (615) 741-2275
Texas		Texas Department of Water Resources P.O. Box 13087, Capitol Station Austin, TX 78711 (512) 475-3187
Utah	Deputy Director Environmental Health Services Bureau 150 W. North Temple Salt Lake City, UT 84110 (801) 533-6121	Bureau of Water Quality Environmental Health Services Bureau 150 W. North Temple Salt Lake City, UT 84110 (801) 533-6146
Vermont	Secretary Agency of Environmental Conservation Montpelier, VT 05602 (802) 828-3357	Department of Water Resources Agency of Environmental Conservation Montpelier, VT 05602 (802) 828-3361
Virginia		State Water Control Board Commonwealth of Virginia 2111 North Hamilton Street Richmond, VA 23230 (804) 257-0056
Virgin Islands	Commissioner Department of Conservation & Cultural Affairs P.O. Box 4340 St. Thomas, VI 00801 (809) 774-3320	Director Division of Natural Resource Management Department of Conservation & Cultural Affairs P.O. Box 4340 St. Thomas, VI 00801 (809) 774-6420
Washington	Director Department of Ecology Olympia, WA 98504 (206) 753-2240	Water Quality Section Department of Ecology Olympia, WA 98504 (206) 753-2966
West Virginia	Director Department of Natural Resources 1800 East Washington Street Charleston, WV 25305 (304) 348-2754	Division of Water Resources Department of Natural Resources 1201 Greenbrier Street Charleston, WV 25311 (304) 348-2107
Wisconsin	Secretary Department of Natural Resources P.O. Box 7921 Madison, WI 53707 (608) 266-2121	Division of Environmental Protection Department of Natural Resources P.O. Box 7921 Madison, WI 53707 (608) 266-0289
Wyoming	Director Department of Environmental Quality Hathaway Building Cheyenne, WY 82002 (307) 777-7391	Water Quality Division Department of Environmental Quality Hathaway Building Cheyenne, WY 02002 (307) 777-7781

REGIONAL HEADQUARTERS, FEDERAL EPA

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	Regional Administrator I Environmental Protection Agency John F. Kennedy Federal Building, Room 2303 Boston, MA 02203 (617) 223-7210
New Jersey, New York, Puerto Rico, Virgin Islands	Regional Administrator II Environmental Protection Agency 26 Federal Plaza, Room 908 New York, NY 10007 (212) 264-2525
Delaware, District of Columbia, Maryland, Virginia, West Virginia, Pennsylvania	Regional Administrator III Environmental Protection Agency Curtis Building, Sixth and Walnut Streets Philadelphia, PA 19106 (215) 597-9801
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee	Regional Administrator IV Environmental Protection Agency 345 Courtland Street, N.E. Atlanta, GA 30308 (404) 526-5727
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	Regional Administrator V Environmental Protection Agency 230 South Dearborn Street Chicago, IL 60604 (312) 353-5250
Arkansas, Louisiana, New Mexico, Oklahoma, Texas	Regional Administrator VI Environmental Protection Agency 1201 Elm Street Dallas, TX 75270 (214) 749-1962
Iowa, Kansas, Missouri, Nebraska	Regional Administrator VII Environmental Protection Agency 1735 Baltimore Avenue Kansas City, MO 64108 (816) 374-5493
Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming	Regional Administrator VIII Environmental Protection Agency Lincoln Tower, Suite 900 1860 Lincoln Street Denver, CO 80203 (303) 837-3895
Arizona, California, Hawaii, Nevada, American Samoa, Guam, Trust Territories of Pacific Islands, Wake Island	Regional Administrator IX Environmental Protection Agency 215 Fremont Street San Francisco, CA 94105 (415) 556-2320
Alaska, Idaho, Oregon, Washington	Regional Administrator X Environmental Protection Agency 1200 Sixth Avenue Seattle, WA 98101 (206) 442-1220

Appendix C

Basis of Costs

These reuse *Guidelines* are not intended for use as a design manual for cost-effectiveness analysis, but rather as a means of making preliminary reconnaissance-level cost estimates to identify some key economic bounds of a proposed reuse program.

Costs of unit processes in these *Guidelines* were based on several engineering reports completed by Camp Dresser & McKee Inc. The reports were based on a comprehensive review of published information on the costs of unit processes and actual construction projects. Table C-1 presents additional wastewater treatment costs and design criteria.

Capital costs include structures, equipment, and nominal costs for electrical, instrumentation, and site work. No unusual structural requirements due to soil or other site conditions were considered. Engineering, legal, administrative, construction supervision and construction contingencies are included.

Construction costs undergo long-term changes in keeping with corresponding changes in the national economy. One widely-used barometer of these changes is the *Engineering News-Record* (ENR) Construction Cost Index. The ENR index is computed from costs of construction and labor, and adjusted for geographical variation throughout the United States. In any given locality, construction costs could be 30 percent above or below the national average. Costs for these *Guidelines* are based on an index of 3000 for mid-1979.

Table C-1. ADDITIONAL WASTEWATER TREATMENT COSTS AND DESIGN PARAMETERS

	COST EQUATION COEFFICIENTS AND EXPONENTS*						
Unit Process	**Capital Costs**		**Annual Operation and Maintenance Costs**				**Design Parameters**
			Materials		**Labor****		
	a	**b**	**a**	**b**	**a**	**b**	
Coagulation and Flocculation	$ 175,000	0.70	$ 28,000	0.80	$ 1,100	0.70	20 mg/l alum
Filtration	210,000	0.90	19,000	0.80	2,750	0.80	4 gpm/sf filtration rate
Sedimentation	155,000	0.90	1,000	0.75	6,200	0.55	650 gpd/sf overflow rate
Separate Nitrification	415,000	0.80	7,700	0.75	7,200	0.55	4-hr detention time includes settling (clarifier 650 gpd/sf)
Two Stage Lime Treatment	386,000	0.85	8,700	0.95	21,700	0.65	400 mg/l CaO
Lime Recalcination	800,000	0.60	90,000	0.90	45,000	0.55	3.5 tons of sludge per million gallons
Activated Carbon Adsorption	915,000	0.80	22,000	0.85	20,000	0.55	4 gpm/sf, 12-min contact time, (includes thermal regeneration and carbon make-up)
Reverse Osmosis	1,200,000	0.80	290,000	0.80	21,000	0.55	90% TDS removal
Chlorination	50,000	0.95	9,000	0.70	5 600	0.60	10 mg/l 30-min detention at average flow
Dechlorination	43,000	0.95	8,000	0.70	5,600	0.60	10 mg/l SO_2

*Cost Equation is: $C = aQ^b$, where

C = costs

a = coefficient of proportionality

Q = average design flow in mgd

b = exponent indicating economy of scale

**Labor based on $10/hr. Should be adjusted to local conditions.

ENR Construction Cost Index = 3000.

All capital costs presented in these *Guidelines* should be expressed in terms of annual or amortized costs. These annual costs for capital can then be added to the projected annual operations-and-maintenance costs to yield a total annual cost, which can be used to compare reuse alternatives. Capital costs of wastewater-treatment processes can usually be broken down to structural and equipment components. Table C-2 shows the equivalent annual cost factors for various service lives. The factors are based on a 7% interest rate, which is approximately the rate required for cost-effectiveness analysis.

The planning period for economic comparison should be 20 years. Therefore, equipment with a service life of ten years is replaced at the end of ten years. The factors in Table C-2 take this into account. Similarly, if a structure has a 30-year life, it would have a salvage value of one-third its original value at the end of 20 years. This salvage value, which is based on straight-line depreciation, is also reflected in the conversion factors.

Table C-2. TO CONVERT CAPITAL COSTS TO EQUIVALENT ANNUAL COSTS (AT ASSUMED 7% INTEREST RATES)

Service Life	Conversion Factor
5	0.243
10	0.142
15	0.112
20	0.094
30	0.086
40	0.082
50	0.079

As an example of using this method of cost estimating, consider the example presented in Chapter 3 for additional treatment facilities. The first thing that must be done is to break out the structural and mechanical components of each unit process and determine their individual service lives. Using the conversion factors in Table C-2, you can separate annual costs for each component. The computations below show how this might be accomplished:

Coagulation		
$200,000	(structures, 40 years) x .082	= $16,400
340,000	(equipment, 15 years) x .112	= 38,100
$540,000		**$54,500**
Filtration		
$450,000	(structures, 40 years) x .082	= $36,900
440,000	(equipment, 20 years) x .094	= 41,400
$890,000		**$78,300**
Disinfection		
$ 75,000	(structures, 40 years) x .082	= $ 6,100
25,000	(equipment, 5 years) x .243	= 6,100
100,000	(equipment, 15 years) x .112	= 11,200
$200,000		**$23,400**
Total		**$156,200**

For the example presented above, use of the more accurate method changes the unit cost from $163,000, calculated in Chapter 3, to $156,000. Generally, this type of cost analysis is not necessary for most reconnaissance-level reuse planning.